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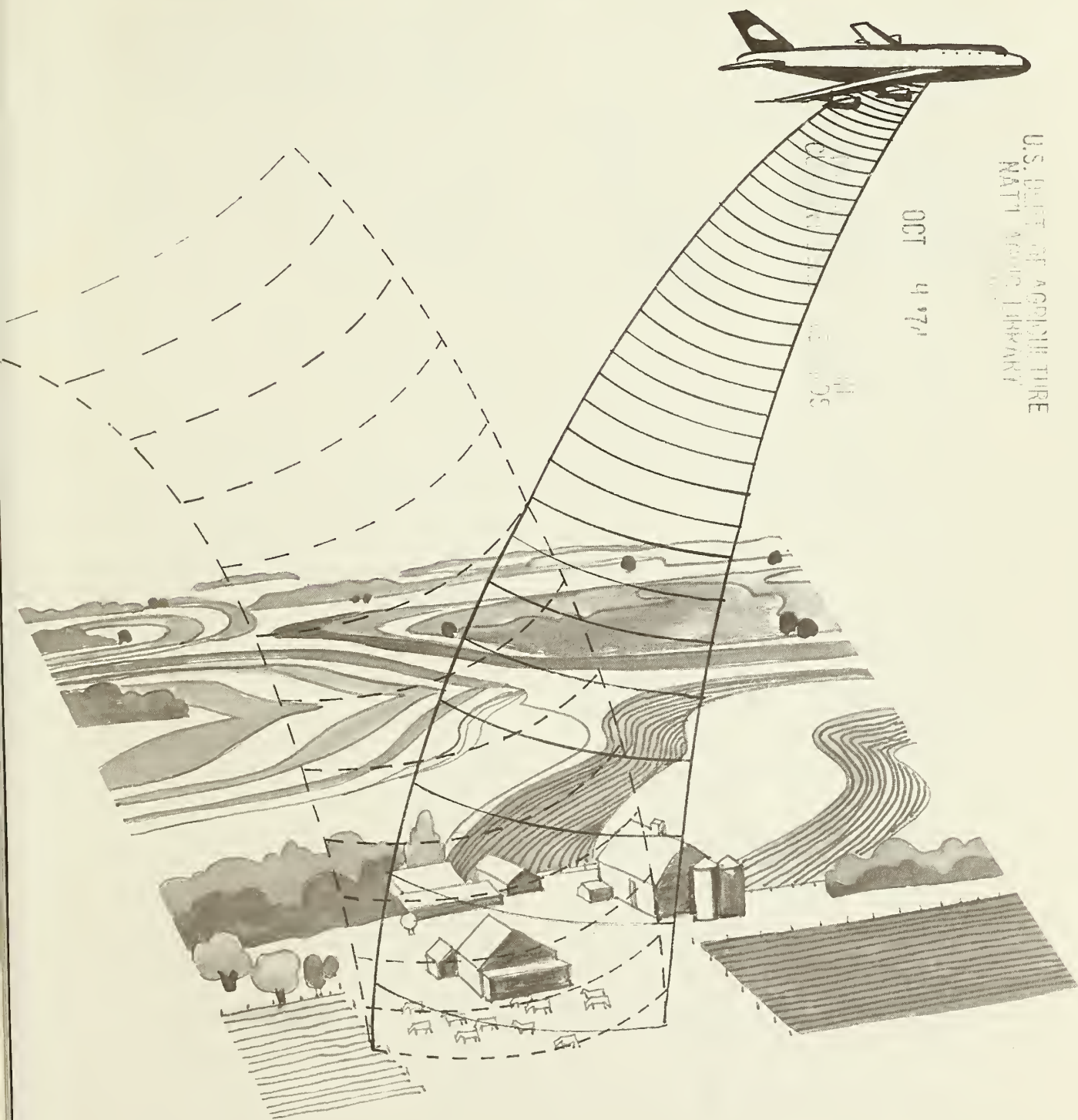
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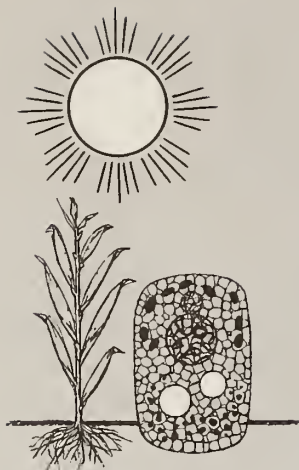
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On Creativity

A Guest Editorial by Cecil H. Wadleigh

Over the past decade, public agencies have put forth a great deal of effort to improve management procedures. Their objective: optimal use of appropriated funds. More sophisticated procedures of program evaluation have been set forth. More rigorous accounting systems have been made available. Less delegation of authority has been adopted to focus responsibility on the top manager.

Obviously, efforts to make the taxpayers' dollars more effective are highly commendable. To this end, it is of interest to consider the efficiency equation engineers like to use:

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}} \times 100$$

Management improvement has striven to improve the effectiveness of the input of funds for research. But research has only one output, only one product—ideas. These include ideas for better mechanisms, better methods, better varieties, better livestock management, better and more acceptable pest control, better watershed protection, and so on.

Thus, the output in the above equation in research endeavor depends entirely on the motivation and proficiency of creative minds having improved intellectual insights on relevant problems.

Psychologists tell us that creative people are adept at restructuring ideas. They abound in curiosity, in questioning ability, and in resourcefulness. They are usually independent spirits, dominant, self-assertive, and diverse in their interests. Creative people have complex personalities. Some would even say they are "oddballs." They appear to march to the beat of different drums than the one that guides the conventional man-on-the-street.

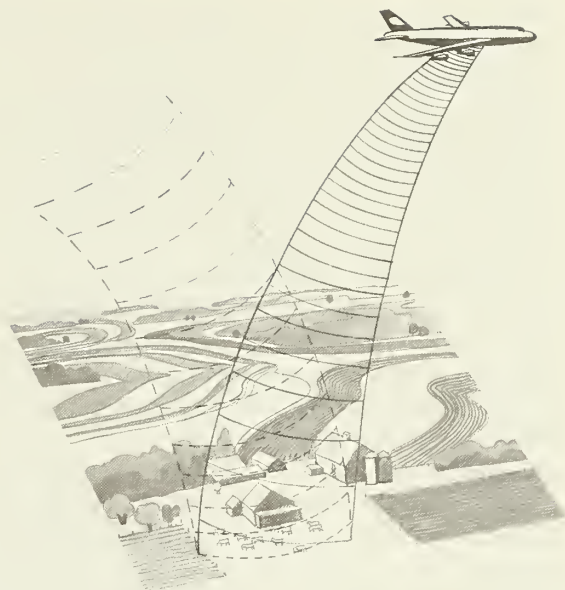
There is no way, however, for a supervisor to make a creative person have a superior flash of intellectual discernment. There is no way for program planners or budgetary accountants to make a researcher mentally synthesize conceptions from discrete disciplines into a valid innovation that helps meet a real problem.

No administrative edict could have made Herr Professor Nernst derive his famous equation in elec-
(Continued on page 14)

NOISE

Its Effect on the Physiology and Behavior of Animals

JAMES BOND



THE constantly increasing intensity of ambient sound in the modern world is now recognized as a form of environmental pollution that can have serious adverse effects on the organic, sensory, and other physiological functions of man, as well as on his behavioral patterns. Although extensive studies have been made on the responses of man and laboratory animals to various kinds and intensities of sounds, little research has been conducted on the effects of noise on animals, particularly farm-raised animals.

Most farm animals, of course, are seldom exposed to sounds of extremely high intensities. However, a number of factors must now be recognized as having the potential for increasing stress in animals: the location of animal production units—particularly poultry—near metropolitan centers, the growing tendency toward production units with large populations of animals, and the rising incidence of ambient sounds in the modern world—particularly within the environments under which animals are now produced.

Any environmental factor that places farm animals under severe stress can decrease efficiency and profits. Therefore, there is a need to know how well present noise levels are tolerated by livestock, and

whether noises of still higher intensities and greater frequency will interfere with efficiency of production.

Effects on Cattle

ONE of the earliest studies directly related to this area of research was that conducted by Ely and Petersen (10)¹ in the late 1930's at the Kentucky Agricultural Experiment Station. Actually, the study was concerned primarily with the factors involved in the ejection of milk in an effort to learn why cows habitually "let down" or "hold up" their milk. In one phase of their study, these researchers created fright stimuli caused by exploding paper bags every 10 seconds for 2 minutes just prior to attaching the mechanical milker. Such stimuli resulted in an immediate cessation of milk ejection. Thirty minutes after the fright stimuli, hand milking produced only 70 percent of the normal amount of milk. Intrajugular injections of adrenalin produced somewhat the same results.

The advent of jet aircraft and supersonic flight in the late 1940's and early 1950's and the accompanying growth of the aircraft industry introduced new

¹ *Italic numbers in parentheses refer to Literature Cited, p. 10.*

sources of noises, some of which allegedly caused losses on livestock and poultry farms. Because of the growing number of complaints—and in some cases the filing of lawsuits—the U.S. Air Force requested proposals for a study, and in 1957 the Department of Agriculture was authorized to investigate the effects of aircraft sounds on dairy cattle. Objective of this study (16) was to determine if there was any measurable effect of jet aircraft noise and flyovers on the milk production of dairy herds located in the vicinity of existing air bases. Data covering a period of 12 months were obtained on the daily milk deliveries from 182 herds located within 3 miles of 8 Air Force bases using jet aircraft.

Thirteen percent of these herds were within one mile of the end of any active runway; 31 percent were between 1 and 2 miles; and 56 percent were between 2 and 3 miles distant. The herds were also classified as “exposed” or “not exposed” to flight activity according to their location regarding the path of take-off and landing for the aircraft.

An analysis of data from 42 herds surrounding the Lockbourne Air Force Base, Ohio, and from complete data on flight activity at that base did not show any evidence that flyovers or proximity to the ends of the active runways had an effect on the milk production of the herds. Comparisons at this base were made between days of flight activity and no activity as well as between the areas mentioned above. Analyses of the less complete data available at the other seven bases confirmed the results obtained at the Lockbourne Base. Results of this survey showed no evidence of an effect on milk production of dairy cattle resulting from flyovers by jet aircraft or proximity to the air base.

Casady and Lehmann (7) selected animal installations for observations on animal behavior under sonic boom conditions in areas near Edwards Air Force Base, Calif. Numbers of animals observed in this study were about 10,000 commercial feedlot beef cattle, 100 horses, 150 sheep, and 320 lactating dairy cattle. Booms during the test period were scheduled at varying intervals during the morning hours, Monday through Friday of each week. The land area around Edwards Air Force Base had been exposed to about 4 to 8 sonic booms per day for several years prior to this study, but the intensity of the previous booms was somewhat less than those presented during the sonic boom tests of this study.

Observers were stationed to watch specified

groups of animals and to note behavior patterns of the animals just prior to, during, and immediately following each boom. They also noted disturbances caused by low flying aircraft used in noise tests.

Results of the study showed that the reactions of the sheep and horses to sonic booms were slight. Dairy cattle were little affected by sonic booms (2.6–.75 pounds per square foot (psf)). Only 19 of 104 booms produced even a mild reaction, as evidenced by a temporary cessation of eating, raising of heads, or slight startle effects in a few of those being milked. Milk production was not affected during the test period, as evidenced by total and individual milk yield.

In beef cattle, the daily frequency of total changes in activity was somewhat lower after sonic booms at a farm much closer to the flight track than another farm. This may simply reflect observer differences in judging activity changes in animals. At all farms there was an apparent decrease in activity after 16 days of sonic booming which might be attributed to adaptation to noise. However, it is also possible that this was due to animal adaptation to the presence of observers.

Casady and Lehmann (7) developed a summary by species and farms indicating that the few abnormal behavioral changes observed were well within the range of activity variation within a group of animals. They defined these changes as horses jumping up and galloping around the paddock, bellowing of dairy cattle, and increased activity by beef cattle.

Since so few abnormal behavioral changes were evident in the Edwards Air Force Base test results, it seemed advisable to conduct some closely controlled observations on normal changes in behavior of animals. Therefore, a series of tests were conducted at the Agricultural Research Center, Beltsville, Md., with groups of beef cattle, dairy cattle, and sheep to supplement the Edwards Air Force Base studies. These groups were observed by two individuals per group, working independently, from 9 to 11:30 a.m. on three consecutive days.

From these data, differences among classifiers, days, and time periods of a day were observed. Each of these effects was evaluated statistically. In the Edwards Air Force Base data, the pertinent figures are simply the percentages of normal changes for each of the species. When the values obtained in the Beltsville study were compared to percentage

changes in activity among animals at the test farms at Edwards Air Force Base, it was concluded that the booms had very little effect on changing the behavioral pattern of farm animals. The assumption is that behavioral changes in activity among animals at Beltsville would reflect normal activity changes among animals at the test farms at Edwards Air Force Base. It was therefore concluded that the observed behavior reactions of large animals to the sonic booms were minimal. Reactions by animals were more pronounced, however, to low flying subsonic aircraft noise than to booms. The reactions were of similar magnitude and nature to those resulting from flying paper, the presence of strange persons, or other moving objects which may indicate that stress may be more pronounced when an object is seen.

In a review paper by Bell (4), the sonic boom effect on beef cattle moving from winter to summer pasture was described as an initial startled reaction (13). Recorded overpressures reached 144 psf, and farmers in the area reported only minor visible response by their animals to the booms—such as a short scattering run of 10 to 30 yards and a subsequent return to grazing. Pilots observed horses and cattle moving away from approaching planes, indicating the possibility that animal reaction may have been caused more by visual rather than auditory stimuli. It should be noted, however, that animals in the area under study had been previously subjected to sonic booms, low-flying aircraft, and blasting noises.

Effects on Swine

DAWSON and Revens (9) studied the behavior of 42 female pigs by using an electrical sparking device which caused a bluish white spark and made a distinct, though not loud, hissing and crackling sound. They found that while many of the pigs were appreciably bothered by the spark at first, almost all the pigs showed very rapid adjustment to it. No association was found between the average time required by the pigs to return to feeding and their average daily gain. In those females which raised litters the next spring, no relation could be shown between previous treatment and whether one or more of her suckling pigs were or were not crushed by her during early lactation because the death loss was similar to that of the control. No relation could be shown between the weekly weight of the suckling

pigs raised by the sow and the time required by the sow to return to feeding during the previous test.

To determine possible harmful effects of aircraft noise, pigs, boars, and sows were exposed at Beltsville, Md., (5) to reproduced aircraft and other loud sounds at various stages of the life cycle. The swine unit, animals, and diets used were typical of those found at most swine production operations. The sound reproduction system consisted of a tape reproducer, amplifiers, horn-type loud-speakers, and control equipment. The tape recording used in these studies was of propeller-driven and jet aircraft in flight and airfield background noises. Schedules of jet and B-36 flyovers was random so that the intervals of sound and no-sound periods were not uniform.

Observations were made of animals during exposure to the following sounds: fixed frequency (104 to 120 decibels (db)); varying frequency (from 200 to 1,200 cycles per second (cps) at 100 to 115 db); alternating sound and quietness (450 to 4,500 cps at 115 to 120 db); and the recorded squeal of a baby pig at 110 db.

The typical reaction of a nursing sow to those sounds was initial alarm during which she arose to her feet and appeared to search for the source of sound, followed by resumption of suckling by the baby pig and apparent indifference to the sound. When suckling pigs were exposed to the sounds in the absence of the dam, they appeared to be alarmed and crowded together. No differences were detected in the responses to the various sounds used; sounds of frequencies ranging from 200 to 5,000 cps at 100 to 120 db intensity elicited like responses, while the effect of a recorded squeal of a baby pig reproduced at 100 db was similar to that of the other sounds used. A detailed report of behavior during exposure to loud sounds is given elsewhere (21).

Boars and sows were almost entirely indifferent to loud sounds during mating. Conception rate of exposed sows was similar to that of unexposed sows. Neither the number of pigs farrowed nor the number of survivors were influenced by exposure of the parents to sounds during mating. Sows were exposed to reproduced sounds from 6 a.m. to 6 p.m. at 120 db 3 days before farrowing until their pigs were weaned. The birth weight and weaning weight of the experimental pigs were higher than the control pigs.

To simulate conditions in proximity to an air-

field, weaned pigs were exposed to jet and propeller aircraft sounds reproduced at 120 to 135 db daily from 6 a.m. to 6 p.m. from weaning time, or earlier, until slaughter at 200 pounds body weight. Five trials were carried out with 3 to 5 groups of 4 to 6 weaned pigs each. Aside from ambient sound levels, environmental conditions were similar for all groups. An analysis of variance failed to show a significant difference between the rates of gain of treated and untreated groups. Feed intake, efficiency of feed utilization, and rate of gain of treated and untreated pigs were similar.

Measurements of heart rate before, during, and after sound exposure were made of a large number of weaned pigs to supplement the prior production results. A telemetering electrocardiograph that recorded heart action without necessitating the presence of attendants in the acoustical chamber was employed to eliminate possible errors due to unfavorable responses of the animals to the presence of humans. These studies showed that the heart rate was significantly increased during exposure but that

Man's Concept of Animals

We need another and a wiser and perhaps a more mystical concept of animals. Remote from universal nature, and living by complicated artifice, man in civilization surveys the creature through the glass of his knowledge and sees thereby a feather magnified and the whole image in distortion. We patronize them for their incompleteness, for their tragic fate of having taken form so far below ourselves. And therein we err, and greatly err. For the animal shall not be measured by man. In a world older and more complete than ours they move finished and complete, gifted with extensions of the senses we have lost or never attained, living by voices we shall never hear. They are not brethren, they are not underlings; they are other nations, caught with ourselves in the net of life and time, fellow prisoners of the splendour and travail of the earth.

From *The Outermost House*
By Henry Beston

it decelerated rapidly after the sound was discontinued while the pattern of the electrocardiogram appeared to be unchanged. In trials in which previously unexposed pigs were exposed to loud sound, differences in response between intensities ranging from 100 to 130 db were just below the level of significance. A significant intensity effect was found when previously exposed animals were subjected to sounds of 120, 130, and 135 db. No significant difference was found in responses of unexposed pigs to frequencies ranging from 50 to 2,000 cps at 110 to 120 db.

Ramm and Boord (17) studied the effects of aircraft noise on the cochlea of the ear of experimental pigs from the USDA study (5). They found no evidence of injury caused by exposure to jet and propeller aircraft sound. A morphological and histological study of the organ of Corti of 39 experimental animals showed no evidence of severe or extensive injury as compared with the normal ear. Minor variations noted in the organ of Corti were of such a nature that in this study it could not be determined if they were due to delayed fixation, tissue artifacts, or minor noise injury. Histological examinations were also made of the thyroids and adrenal glands of pigs that had been exposed to recorded aircraft sounds of intensities up to 135 db. No evidence of injury or changes suggesting impaired function was found. None of these investigations (5, 9, 17) has yielded evidence indicating that swine are influenced significantly by noise.

Bugard *et al.* (6) studied the neuro-endocrine system of young castrated male pigs. They found that noise of 93 db for several days caused aldesteronism and severe retention of water and sodium. They also noted that sounds ("alarm signals") recorded from pigs in the slaughterhouse were more disturbing than noise from mechanical sources.

Effects on Poultry

SOME research has been done in the United States on the effects of noise on poultry. Most of the recorded studies deal with sonic boom effect which apparently were prompted by claims from hatcherymen soon after the advent of supersonic flights.

Heinemann (13) reported a 1965 study conducted by the USAF Environmental Health Laboratory, Kelly AFB, Texas, to determine the effects of sonic booms and low-flying subsonic aircraft on

poultry and poultry eggs. The test site was White Sands Missile Range, New Mexico, where the Federal Aviation Agency was conducting the National Sonic Boom Structural Response studies. Sonic booms were produced by supersonic aircraft approaching the site from eight different directions, creating free-field overpressures in the range of 3 to 19 pounds per square foot.

Five different sets of incubating eggs, totaling 3,415 eggs, were exposed to sonic booms for varying numbers of days. A control zone was established 50 miles away from the test site so that control eggs and experimental eggs not being "boomed" could be protected from shock waves.

The eggs were incubated in small commercial-type incubators, each capable of holding over 2,000 eggs. Condensor microphones were shock-mounted inside the incubators so that intra-incubator overpressures could be recorded. Overpressures in the test site incubator ranged from 0.3 to 4.8 pounds per square foot; levels in the incubators at the control site never exceeded the background noise produced by fans inside the incubators.

At the end of the incubation period, during which over 600 sonic booms were produced at the test site, the hatch was taken off, and hatchability and teratogenic data were collected. No significant difference in these parameters was found between exposed eggs and their corresponding controls except in one group where the control eggs were noticeably lower in hatchability and number of functional chicks and higher in mortality. The mean hatchability of all exposed eggs was 83.2 percent; that of the controls was 81.3 percent. These data also fell within the range of hatchability reported by the egg supplier on hatches of this particular variety of eggs in his hatchery.

Ten percent of the hatched chicks from each test and control set were subsequently raised to sexual maturity and put into egg production. No differences were found between test and control birds in weight gain, feed conversion, onset of egg laying, or egg production. Pathological studies were made of randomly selected, 12-week-old birds from each set; no gross or microscopic differences were found.

It was concluded that sonic booms of equal or greater overpressures than are normally created by operational aircraft or supersonic transport do not adversely affect the normal development of chick embryos and their subsequent growth.

A second study reported by Heinemann (13) attempted to determine the effects of aircraft noise on broilers and laying flocks. This study was made in west-central Arkansas where one of the major U.S. poultry production areas is located. Most of the poultry farms there are large-scale operations which consist of two or more poultry barns, each housing over 10,000 birds.

Sound-pressure-level recording instruments and remote-controlled motion picture cameras were located on 11 poultry farms, housing broilers 1 to 9 weeks of age and laying chickens 20 to 62 weeks of age. More than 600 low-level missions were flown over the poultry farms in this area of Arkansas, and poultry exposed to 75 of these overflights were filmed and accompanying sound-pressure levels recorded.

During low-level overflights, which produced sound-pressure levels of 85 to 140 decibels in the barns, the birds commonly stopped their usual activities and exhibited what could be termed an "alert" reaction. They quieted down, attempted to locate the source of the noise, and then either maintained their position or moved away from the area from which the aircraft was approaching. When flock "movement" occurred, it was never a panicky stampede but merely a shift of the flock away from the approach-side of the building.

Young chicks tended to move a greater distance in response to the approaching aircraft than did broiler-sized birds or birds in layer flocks. Crowding and piling up was never a problem. No injured, smothered, or crushed birds were ever seen following an overflight.

There was no evidence from production records, maintained by the large cooperative that owned most of the poultry in this part of Arkansas, that egg production, weight gains, feed efficiency, or flock mortality were altered by these aerial operations.

A study by Hamm (11) published in 1967 was the direct outgrowth of alleged loss of egg production in South Carolina from army maneuvers Swift Strike in 1963 and 1964. Poultry producers claimed that during the height of the maneuvers their egg production dropped 20 percent and the total loss during the period was \$250,000.

Hamm's study showed that a single short stress of aircraft noise was not damaging, but that longer

periods of stress (three days or more) did affect production. He concluded, however, that the stress *per se* did not affect egg production, but instead kept hens from feed and water which in turn caused egg production loss.

According to Stadelman (19), his studies showed that recorded aircraft sounds of 96 db inside an incubator and 131 db outside caused no damaging effects to eggs. Sounds of 115 db did, however, interrupt the setting tendencies of broody hens. His experiments with day-old broiler chicks continuing through market age showed no adverse effects from recorded aircraft noise.

One of the more recent research projects is that now being set up by South Carolina. Titled "Effect of Noise Pollution on the Fowl," two of the objectives are to determine (a) the hearing range of chickens and (b) the degree of sound intensity that can produce damage to fowl hearing organs. Certain phases of the study will involve the use of recorded hawk cries.

Effects on Mink

A fair amount of research attention has been directed to the effects of noise on farm-reared mink, which are characteristically sensitive to stress. As with other animals, some of the studies were initiated to determine the legitimacy of damage claims from producers.

Pallen (15) reported that if a female mink becomes nervous she is very liable to unintentionally kill some, if not all, of her kits in an attempt to protect or hide them. Such worry and excitement may also cause hardening of the mammary glands and, being unable to nurse, the kits will die. Low flying planes and severe electrical storms have caused losses of very young kits. Hartsough (12) reported that noises or disturbances to which the mink are unaccustomed may result in kit losses.

During the spring of 1967, a study (20) was conducted by USDA's Agricultural Research Service on two commercial mink farms in Virginia to determine the effects of simulated sonic booms upon pregnancy, parturition, and kit production of farm-raised mink. Sonic booms were simulated by a large horn into which 2 charges of compressed air were released sequentially by time-controlled ruptures of the two diaphragms. This produced overpressures of 0.5 to 2.0 pounds per square foot. Three hundred

breeding pastel females and over 1,250 kits were used in the study.

Mink were boomed four times between 0930 and 1130 and four times between 1300 and 1530 from April 8 to June 1 at a special experimental site. The times were picked at random with no less than 10 minutes between booms. An approximate equal number of mink were kept at the control farm and were not boomed. Since all groups of mink were bred in a similar manner before the moving or booming was initiated, the production of kits per female whelping is considered to be the most valid criterion of reproductive performance in this experiment.

Kit production per female on experiment for the mink receiving the sonic boom treatment with statistically higher than that of the control (724 live kits at 10 days from 180 females for an average per female kept of 4, compared to 427 live kits from 120 females for an average of 3.6). This was primarily because of a higher percentage of females whelping. The percentage of females whelping was 91 percent for the boomed mink compared to 78 percent for mink that did not receive the boom.

On a basis of kits per female whelping, the mink receiving the sonic boom treatment had essentially the same litter size at 10 days (4.4 kits per female whelping compared to 4.5 kits per female whelping in the groups not boomed).

The highest percent of kit mortality was for mink boomed the entire period. This contributed to slightly higher mortalities in the boomed group and the group whelped at the farm where mink were boomed. However, the overall production (kits per female on experiment) was higher for boomed mink and for mink whelping at the farm where the mink were boomed.

No effect could be attributed to differences in intensity of the boom, and there were no visible indications that repeated booming caused increased excitability or nervous reactions.

Under the conditions of this study, no harmful effects to mink were observed that could be attributed to exposure to the simulated sonic booms. Reproduction in both the boomed and not-boomed groups could be considered normal.

One of the most recent research studies on the effect of noise on mink was an interdisciplinary one conducted cooperatively in 1970 by the U.S. Depart-

ment of Agriculture, U.S. Air Force, University of Alaska, and Washington State University.² Aim of the project was to determine the effects of real and simulated sonic booms on the behavior, reproduction, and growth of farm-raised mink.

The study was conducted on Mitkof Island, near Petersburg, Alaska—a location chosen because mink are successfully raised there, experienced personnel were available for management, test mink could be isolated for booming without booming the control site, and isolation would eliminate other possible disturbance of the animals.

Test animals were violet colored and homozygous for the recessive aleutian genes. Mink with this genetic background are less hardy and more difficult to raise than mink not homozygous for the aleutian genes, thus providing a stringent test of possible adverse effects of sonic booms under farm conditions.

On May 11, when 40 percent of the females had whelped, mink at the “boom” site were subjected to three sonic booms produced by a U.S. Air Force

F-4 Phantom jet plane on straight-level flight path at 8,000 feet moving at speed Mach 1.2. Overpressures measured on ground plane averaged 6.45 pounds per square foot for the 3 booms.

On May 12, mink at the “simulator” site were subjected to three simulated booms produced by a device made for this purpose. It consisted of a 13.5-foot-diameter exponential horn into which two charges of compressed inert gas could be released suddenly from the small end by rupture of thin diaphragms, producing a pressure pulse propagated from the horn. Mink nearest the simulator were subjected to overpressures of 5.8 pounds per square foot.

Observers recorded running descriptions of ongoing activity of females for 3 days prior to boom at the “boom” site to provide baseline data on behavior of undisturbed females during whelping season. Similar observations on May 11 included the period before, during, and after booms. Other observers obtained similar information at the “simulator” site on the day before and the day of the simulated boom.

Following both real and simulated sonic booms,

²This report is in the process of being published. At the time this article was written, publishing data were not yet available.



Noise and Man

A possible teaching of a recent critical and historical analysis of environmental noise¹ is that, other than as a damaging agent to the ear and a masker of auditory information, noise will not harm man or interfere with his mental or motor performance.

According to this concept, man should be able to adapt physiologically to his noise environment, with only transitory interference effects. Yet this concept, or its converse, is difficult to substantiate by scientific research and must be recognized as hypothetical at this time.

Because of the striking similarity of the organ of hearing among people, both the auditory damaging effect and the masking of information can be predicted and measured with considerable accuracy. Not so, however, with other physiological stress reactions. People tend to respond differently to noise, and—depending on the character of the stimulus—may exhibit annoyance, frustration, or fear. Authorities seem to agree that if such stress reactions are not eliminated through learning, they would undoubtedly be harmful to mental and physical health.

¹ *The Effects of Noise on Man*, Karl D. Kryter, Academic Press, N.Y., 1970.

the reaction of most female mink appeared to be brief and of little consequence to on-going behavior. General activity returned to levels comparable to those observed on days of baseline observations within 5 minutes after each boom. Decrease in overt response to each successive boom suggested that the observed females adapted quickly to recurring sonic booms not accompanied by other sensory cues to danger. No activity suggesting continued arousal or general panic within the colony was noted.

Necropsy examinations of all mink that died immediately before or immediately after exposure to booms (April 30–May 13) indicated spontaneous disease commonly found in ranch aleutian mink. None of the deaths could be related to sonic booms. Bacterial examination of animals that died or were

sacrificed likewise gave no evidence that bacterial disease was induced following exposure to booms. Examination of females and kits 8 weeks after exposure to booms indicated infection by pyogenic bacteria, but it did not appear to be related to the treatments. No evidence of aleutian disease, mink virus enteritis, canine distemper virus, or mink encephalopathy was found.

Effects on Sheep

A limited amount of research has been conducted on the effects of noise on sheep. In a Kansas study (1) 10 early weaned lambs were subjected to 12 days of continuous 75 db noise followed by 12 days of continuous 100 db noise. A second group was subjected to 12 days of continuous 100 db noise. A 14-day control period (background noise of 45 db) preceded each trial. Data were collected on heart and respiration rate, oxygen consumption, and pituitary, ovary, and uterine weights. There were significant changes in heart rate, and adrenal and pituitary weights declined during sound exposure. Lambs in the 75 db group gained more than those in the 100 db group and the controls.

Two other Kansas sheep studies (2, 3) indicated that (a) sound intensities of 90 db inhibit the release of thyroid hormones, and (b) the audiogram curve for sheep occurs at a higher frequency than for humans.

As previously noted in Casady and Lehmann's study (7) on horses, cattle, and sheep, reactions of sheep to both actual and simulated sonic booms were slight.

Research in Other Countries

RESEARCH on the effects of noise on farm-raised animals in foreign countries has followed somewhat the same pattern as that in the United States. The most recent research, however, concerns primarily the effect of sonic booms, and in most instances the results are negative. A number of these studies were discussed at an international conference on sonic noise held in Stockholm, Sweden in 1971.

The French research program appears to be an on-going one and covers studies on the reactions of poultry, swine, cattle, and bees—also on life organisms (chick, pheasant, and partridge embryos during hatching) exposed to sonic booms. One of the aims of the French research is to determine the

maximal frequency and intensity which animals can endure without any damage. Cottureau (8) has reported that chick embryos exposed to six simulated sonic booms daily were not affected by the noise. However, broilers that had been exposed to six sonic booms since birth showed a marked startled reaction and stopped all activity for 20 to 30 seconds whenever boomed. The growth rate and efficiency of these broilers were normal.

Ruddelsden (18), a British researcher, has studied the sonic boom effect on laying birds. Originally, his study was set up with pheasants as the subject birds, but a flock of lapwings had established nests in the vicinity of the test range, and he decided to include them in the experiment.

The lapwings appeared to be unperturbed by the booms, and the process of laying, incubation, hatching and chick rearing was accomplished in a natural manner. Daily egg production trend of the pheasants appeared to fall on days subsequent to boom activity, but, when compared with trends pertaining to the same pheasantry over two other seasons during which no boom activity occurred, the similarities implied that the day-to-day variations were due to some influence other than the effect of the simulated sonic booms. Rate of fertility in the pheasantry was highest for the season when sonic booms were experienced.

Ruddelsden believes the evidence obtained from his observations tends to indicate that the laying habits within these two species of birds will not be adversely affected by the anticipated supersonic flights of transport aircraft.

Quite in contrast to the generally negative results reported elsewhere, a 4-year Japanese study (14) in the late 1950's reported severe reactions and reduced milk flow of 5 dairy cows housed near the site of speed boat races running 72 hours a month for several months. The lowered lactation curves coincide exactly with the periods of high noise intensity; however, the small size of the sample tested is far from ideal.

As a part of the same Japanese study, laying hens housed 20 meters from a busy highway and a railroad track were observed for nearly a year. Hens that had been originally hatched and raised at the site appeared to pay no attention to the traffic noise and their egg production was near normal. However, 50 60-day old chicks brought in to the test

site from another farm appeared nervous for the first 7 weeks, after which they showed little concern for the noise.

Conclusions

ON the basis of the research studies conducted to date, it seems reasonable to conclude that sonic booms from aircraft have little or no effect on the behavior and productive capacity of farm-raised animals—at least at the intensities and frequency of occurrence to which they have been exposed so far. Most of these studies were initiated primarily to obtain reliable data on which to base decisions about damage claims allegedly resulting from supersonic aircraft flying over animal installations. The incidence of such claims had been rising sharply since 1961 and reached a peak in 1964. During the 10-year period from 1961 to 1970, the U.S. Air Force reported 238 claims totaling \$898,000 (4). Of these, only 98 were allowed and the total amount awarded was \$127,953. Most of the claims were for alleged mink losses. In 1970, only one claim was filed—for \$275—and it was disallowed. Apparently some mink ranchers are not yet convinced that sonic boom causes no adverse effects to their animals, and it was largely for this reason that the previously mentioned comprehensive Alaskan study was initiated.

Even though research has given us some solid answers about the effects of sonic boom on farm-raised animals, our knowledge about the stress effects of the rising incidence of ambient sounds which most animals endure is still rather meager. Few if any studies have been set up in the United States under settings similar to the previously cited one in Japan. Perhaps eventually we will learn that farm animals have a greater capacity to endure sound stress than has been demonstrated for man. But the full answers to the problem have not yet been brought out by research.

Much of our present knowledge about the effects of noise on farm animals has resulted from only a few planned studies. We know even less about the effects of noise on wildlife, although a number of incidents have been recorded indicating that the effects can be even more detrimental than on domestic animals. Admittedly, planned studies in this area would be difficult to set up. Therefore, whatever knowledge we glean may have to come from further and more comprehensive studies on those animals over which we have some control. The

present consensus seems to be that noise pollution is primarily a concern of man. But do we know

enough to conclude that the animals on which we depend are immune to its effects?

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Can We Make Our Agricultural Research More Efficient and Effective?

WYNNE THORNE

THE three faces of land grant universities—classroom teaching, extension or public service, and research—are widely eulogized as an ideally balanced way to serve important needs of society. The agricultural segments of these programs have been the pioneers, and have served a successful industry well. But during the past 10 years there has been a dramatic shift of resources and public acclaim to programs and organizations supported under more competitive funding systems. If the institutions and relationships that were so productive in the past are not best suited to the present or some future era, then they should be modified. Before initiating any drastic revision, however, it appears prudent to try to cure some of the most debilitating weaknesses with something less severe than major surgery. While my emphasis will be on research, any action programs would obviously have

to allow for interactions with classroom teaching and extension.

Many institutions are critically reviewing their agricultural teaching-research-extension combinations with the intent of altering their organizational arrangements and procedures, whenever evidence or opinion indicates that changes may be beneficial. Basically, such realignments imply a new definition of objects and benefits. The Purnell Act is often cited as a charter for experiment station programs. It provides funds to conduct “such scientific researches as have for their purpose the establishment and maintenance of a permanent and efficient agricultural industry, and such economic and sociological investigations as have for their purpose the development and improvement of the rural home and rural life.”

Greater Regional Emphasis

IF the major goals of experiment stations remain to insure a stable supply of food and fiber and to improve rural living, then precipitous realignments might amount to discarding the baby with the bathwater. Couldn't our traditional (and still valid) goals be better served by simply seeking a greater regional emphasis in our systems and subsystems of activities?

National, regional and State lists of problems investigated by State experiment stations indicate that few are unique to any one State, and only slightly more are restricted to a region. The natural deduction, then, is that specific research projects should be oriented and organized with attention to State lines only when these lines coincidentally delineate unique differences in problems.

Another pervasive phenomenon is the reluctance of many researchers to assume responsibility for publicizing their findings beyond the immediate step of technical communication with peers. Concurrently, extension workers rarely probe deeply into the technical literature. Thus, potential applications may be first recognized and applied by commercial representatives or by progressive practitioners rather than by extension personnel. This situation could be remedied at each station without invoking regional cooperation, but between-station redundancies would continue to preclude true efficiency.

There is a modicum of agreement among all experiment stations that a more integrated approach to research assessment, planning and execution, and a closer tie between the researcher and the application of his findings are desirable. Steps have been and are being taken toward these ends. Unfortunately the efforts to date have been too few and too feeble.

Reviews and deliberations leading to the Bankhead-Jones Act of 1946 indicated a need for greater regional and national planning and cooperation relative to the conduct of research by State experiment stations. The funds and guidelines provided by this Act generated high hopes for the development of integrated planning and for a concentration of facilities and endeavors to attack problems of regional or subregional significance. Significant benefits have undeniably been realized from regional planning and through cooperation among scientists within and among regions. Never-

theless, we have few examples of distinctive facilities being established or of major regional concentrations of scientists being financed to attack significant problems.

A New Approach to Excellence

THE adopted procedures have been more toward facilitating revenue sharing, and program determinations continue to reside primarily at the State level. True, regional research committees, the Committee of Nine, and regional associations of directors make the rules, appoint task forces to study problems of commodities, and select broad research projects, but the individual States decide whether to participate, which personnel should be involved, and what financial and other resources are to be assigned. Critical reviews of the performance of individual researchers, comparable to those given by National Science Foundation panels, seldom occur. Such dereliction is, I believe, deeply imbedded in human nature and in public policies and pressures.

Each State experiment station is convinced that it has its own distinct ambitions and clientele. These provincialized interests and aspirations, these desires of each station to be more than a cog in a large wheel, these yearnings for excellence could actually be the basis for a general strengthening of our agricultural research programs. But such a transformation requires that we somehow overcome the habit of myopic self interest. One route toward this end could be through a reexamination of the discovery process, the building of research institutions, and our responsibilities as station administrators to provide the knowledge that will insure an ample supply of high quality food and fiber while protecting the environment.

Time for Reassessment

JOHN Gardner, in the October 1965 issue of *Harper's* magazine offered nine rules for preventing organizational dry rot. Some of his observations are relevant to any reassessment of our agricultural programs: "The organization must have fluidity of internal structure. Most organizations have a structure that was designed to solve problems that no longer exist. . . . The organization must find some way for combating the vested interests that grow up in every institution. Nowhere can the operation of vested interests be more clearly seen than in the

THE ARPAC ACTION

At its October, 1971 meeting the Agricultural Research Policy Advisory Committee (ARPAC), on the recommendation of the Agricultural Research Program and Facilities subcommittee (ARPF), adopted a motion that would bring a new concept to regional and national research planning.

The motion carried the recommendation for the following action:

- *Modify the membership of ARPF to provide for better representation of research organizations and to assure coordination of regional planning and implementation at the national level.*
- *Establish a Regional Planning Committee (RPC) in each of the four regions.*
- *Provide an analytical staff for ARPF and RPC's as soon as possible.*
- *Give each RPC the latitude to proceed with establishing regional planning groups or research programs according to its needs.*

I support this action as one avenue toward improved regional research planning. How many more chances are we likely to have before a plan is developed "on the outside" and imposed on our system?—D.W.T.

where a major discovery or development occurs. In today's world, it is wasteful for each station to spread its resources over so many problems, some of which are inevitably the subjects of overlapping or even duplicate programs in neighboring States.

Mobility of Knowledge

THE flow of agricultural information in the United States is tremendous in volume and speed. The U.S. Department of Agriculture has about 4,000 publications available at any one time, and approximately 35 million copies are distributed each year. State Cooperative Extension Services publish an equal or greater quantity of literature geared to reach the farmer, the homemaker and industry. You can then add the large numbers of radio and television programs carrying much of the same subject matter, the information released by commercial companies involved with sales promotion, and the articles in newspapers and magazines. This communication picture leaves little likelihood of significant new information being developed anywhere without an alert agriculturist having repeated opportunities to be informed. If we can agree on today's immediate, massive mobility of knowledge, then we can appropriately inquire as to whether we, as administrators, have adequately planned our strategies for research and extension to take advantage of this situation.

Economies of Scale

ONE indication of our current inefficiency is the extent to which stations are *not* concentrating research on a few selected problem areas to achieve efficiencies and economies of scale. Data were obtained for 10 experiment stations, widely separated geographically, and involving expenditures in 36 subject areas for the years 1951 and 1969. Annual expenditures for research in these stations ranged from \$425,000 to \$2.2 million in 1951, and from \$1.9 million to \$8.6 million in 1969. Out of the 36 possible programs, the 10 stations individually supported investigations in a range of 20 to 30 areas in 1951 and in a range of 22 to 31 in 1969. There was an average increase of 3.6 areas of participation over the 18-year period. No States showed a decrease in program areas. An average of 4.5 new program areas were initiated, while 1.0 was terminated over

functioning of university departments. . . . The organization must be interested in what it is going to become and not what it has been. . . . Most ailing organizations have developed a functional blindness to their own defects. They are not suffering because they can't solve their problems, but because they can't see their problems. They can look straight at their faults and rationalize them as virtues or necessities."

In the beginning, State agricultural experiment stations were relatively isolated entities and were obliged to provide some help, even if only by crude demonstrations, in coping with all problems in their respective States related to agriculture and natural resources. Times have changed, isolation of any sort is a mere memory, and little if any special advantage is likely to accrue to the specific State or region

the 18-year period. No relationship was evident between magnitude of expenditures by an individual experiment station and its number of areas of research activity.

The tendency to disperse resources is further evidence by the fact that between 1951 and 1969, each of the 10 stations studied significantly reduced support of (but did not abandon) 14 areas, and increased support of only 3 areas. The amounts involved in each case equaled approximately 5 percent of total station resources. Also, in 1951, 16 areas in the 10 stations received 10 percent or more of the station funds, whereas in 1969 only 7 areas were so favored. These data indicate a flattening of State programs over the years, rather than the development of peaks of specialization.

Regional Coordination

OBVIOUSLY, cooperation in regional planning can be no better than the planning within individual States. The concentration of research at each State experiment station into a few areas to facilitate distinctive accomplishments admittedly could pose ostensible problems in sustaining educational programs

and in meeting demands of in-State commodity groups for research. These problems could, however, be solved by regional coordination and thoughtful concentration of programs. Strong research affiliations with education are needed primarily at the graduate level, and each State can hardly afford a strong graduate program in every department, and certainly not in the many subdisciplines represented within individual departments. Coordination within a region and facilitation of student "exchanges" would help all participants.

Commodity groups could be helped to see that their real need is for useful information, not for someone in *their* State to be studying *their* problems, even though the efforts be inadequate. A careful meshing of research and extension programs within and among stations would mean that commodity groups in all participating States would get optimum service.

The current sparseness of financial resources should be adequate incentive to seek efficiencies of operation. It would seem that the initiative lies with station directors, who might be well advised to seek cooperation rather than competition within their own ranks.

ON CREATIVITY—(*Cont. from inside cover*)

trochemistry, made Edison invent the light bulb, or made Glenn Burton develop Coastal Bermuda-grass. These creations have to come from the motivation and mental gyrations within the individual.

Although major efforts have gone into management to streamline and make more effective the "input" into the above equation, comparatively little effort has gone into (a) ascertaining ways and means of more judiciously selecting those people who have high potential for creative innovation, and (b) understanding how to provide the physical, administrative, and intellectual environment that will engender the maximum output of new or improved concepts having relevance to pressing problems.

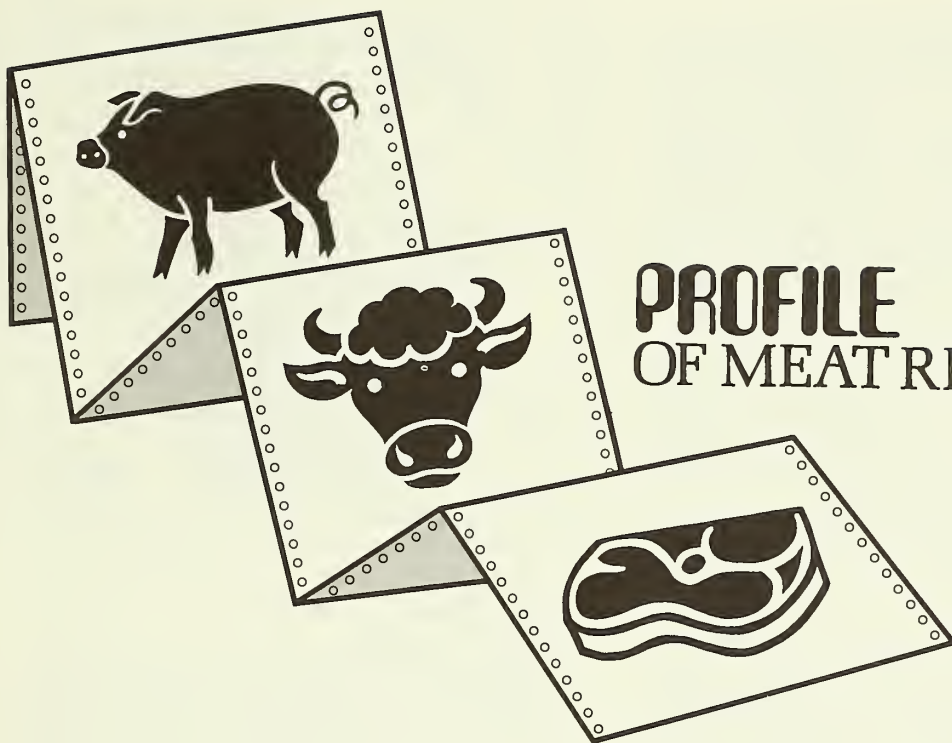
Research is far more than the capacity to operate a sophisticated piece of hardware, or the ability to collect numbers for a computer. Acceptable research must involve a diversity of ideas and information commingled in the mental cauldron with a distillation of new perceptions having real substances.

A good researcher must maintain rigorous self-discipline, but he does not respond well to imposed conformity. He must always question, often deviate from, and sometimes undo the conventional wisdom. Marching to the lockstep is not the way to creativity.

My experience over 20 years in research administration convinces me that racehorse trainers know far more about attaining the maximum potential from spirited steeds than we in research administration know about attaining maximum effectiveness in the output of creative minds.

What's wrong with striving for proficiency in intellectual excellence in our research output?

Cecil H. Wadleigh
Science Adviser (now retired)
Office of Administrator
Agricultural Research Service
U.S. Dept. of Agriculture



PROFILE OF MEAT RESEARCH

S. E. ZOBRISKY

THE following article and the one by H. J. Hodgson in this same issue have something in common that merits a bit of editorial comment. It is hardly likely that either one of them could ever have been written prior to the advent of USDA's Current Research Information System. CRIS, as this ADP system is now commonly called, opened up whole new avenues of research analysis and evaluation that would have been extremely difficult to accomplish by a system of lesser capabilities. Thus, these profiles provide research administrators with new viewpoints and opportunities for evaluation that will

better enable them to assess the merits, the shortcomings, and the gaps in research programs. It is reasonable to expect that, as the capabilities of CRIS become more amenable to use, more such analyses—and perhaps even more revealing ones—will be undertaken.

This article does not purport to be anything more than the title implies—a profile of meat research programs being conducted by public research agencies, primarily the State agricultural experiment stations and the U.S. Department of Agriculture. No attempt is made to draw inferences from or attach significance to any data which the analysis yielded.—Ed.

FOR most U.S. consumers, meat represents the largest per capita expenditure of all food commodities consumed. An average of \$155 per capita

(about 85¢ per pound) was spent to purchase 182 pounds of beef, veal, pork and lamb in 1969. This was equivalent to 30.5 percent of the average Amer-

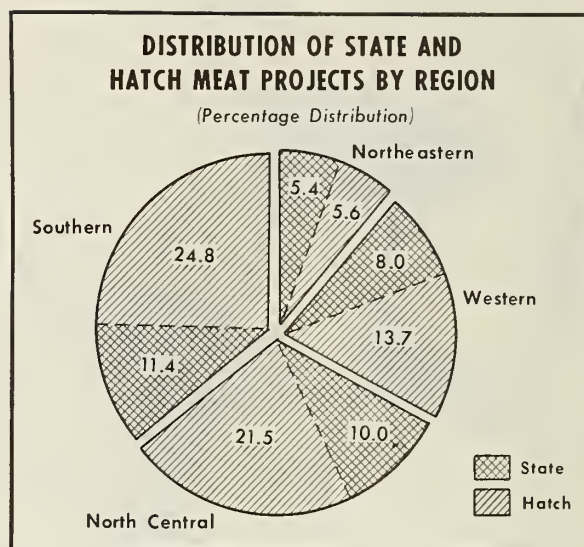
ican's total food expenditure. The meat producer's share of consumer expenditures for meat at the retail level was 57 percent. This amounted to 200 percent more than that received by fruit and vegetable producers and 300 percent more than that of cereal producers. Conversely, the cost of marketing meat was considerably lower than for marketing fruits, vegetables, or cereals. The value of red meat sold to American consumers in 1969 amounted to more than \$31.6 billion.

Research conducted by investigators in State agricultural experiment stations (SAES), the U.S. Department of Agriculture (USDA), and private industry provides the information for improvements in meat production, marketing, acceptability, development of convenience items, maintenance of wholesomeness and safety, and the development of a variety of new types of meat and meat products.

This profile of the SAES and USDA research programs for 1969-70 was developed from records of the Cooperative State Research Service (CSRS), primarily those stored in the Current Research Information System (CRIS). By using information from CRIS, it was possible to obtain information on the following factors:

- Regional distribution of projects by species (commodity) classification.
- Effort devoted to basic and applied research.
- Distribution of effort by disciplines directed to meat problems.
- Distribution of effort devoted to specific Research Problem Areas (RPA).
- Funds obligated per Scientist-Man-Year (SMY) and per Research Problem Area (RPA) in 1969-70.
- Distribution of support funds for SAES agricultural research programs.
- Position of meat research relative to the total SAES research programs.
- Past and present research effort plus proposed increases.

In addition, analysis of data from CRIS should provide some ideas nationally on concentration of effort, current and future problem areas, and some trends in meat science research which may be on a different priority level in an individual State. It should be emphasized that the data that come out of the system are no better than the inputs into the system.



Classification of Data in CRIS

The broadest classifications in the agriculture research system are the 10 goals, which represent 10 national agricultural objectives encompassing all agricultural research endeavors. They provide the framework for developing future research priority areas, evaluating contributions made by current research programs, and for recommending adjustments in such programs.

Most meat research is concentrated under four different goals: protection of livestock from insects and disease (Goal II), expanding demand for farm products by developing new and improved products and processes and enhancing product quality (Goal IV), improving efficiency in the marketing system (Goal V), and protecting consumer health and improving nutrition and well-being of the American people (Goal VII).

Research projects are further classified by one or more of 40 activities, each of which indicates the general purpose of the research. The five activities most pertinent to meat research are: protection from loss and damage; efficient production and consumer acceptability; chemical and physical properties, processing; marketing, quality, and maintenance; and nutrition and consumer satisfaction.

Grouped under 9 of the national goals are 98 research problem areas (RPA), which are subdivisions of activities. Each RPA is assigned to the goal to which its major contribution will be made.

Most meat research projects fit into about 16 of the total of 98 RPA's.

Inter-related to the activities is a further classification dividing the work according to the one or more commodities or resources involved in the research work.

Finally, the fields of science that depict the scientific disciplines employed in solving the problems are identified.

Distribution of Projects

The distribution of meat projects by regions and species between SAES and the USDA is shown in Table 1. Of the 592 SAES and USDA projects that include some aspects of meat research, the heaviest concentration is in beef, followed in order by the unidentified classification, pork, and lamb. The unidentified classification includes much of the basic research on meat proteins, emulsions, fatty acids, connective tissue, etc., and those applied projects which involve two or more species. Approximately half of the USDA projects are in this classification. The SAES have approximately 4.5 times as many projects as the USDA.

The Southern region has the greatest number of projects (81) applicable to beef and also the most projects (62) in the unidentified classification. Pork research in terms of projects is most numerous in

the North Central region (33) followed by the South (28), West (11) and Northeast (7). Lamb research projects are most prevalent in the West and North Central regions.

The State agricultural experiment stations have more projects classified under animal science (336) than under the food science (91) and agricultural economics (56) classifications combined. One-half of projects classified as animal science were concerned with beef; one-fifth with pork; one-ninth with lamb; and one-sixth were not identified with a specific species. Half of the USDA projects were also devoted to beef.

About 150 USDA and SAES meat projects carry a food science classification, most of which are in the Southern and Northeastern regions. Many of the food science and USDA meat projects were unidentified as to species. A possible explanation may be that much of the more basic research is carried out on meat from several species to separate or study species differences in proteins, emulsions, fatty acids, processing characteristics, etc. Such investigations do not readily lend themselves to specific species categorization. The number of projects concerned with pork is greater than those classified as beef and lamb.

Projects that are conducted with the cooperation of at least some economic guidance totaled 74. None

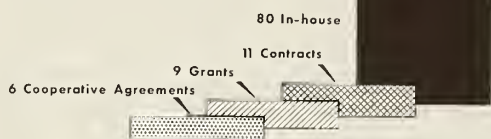
TABLE 1.—*Distribution of SAES and USDA meat projects by region ¹ and by species*

Species	SAES ²					USDA					Total
	NE	S	NC	W	Sub-total	NE	S	NC	W	Sub-total	
	<i>Number</i>					<i>Number</i>					
Unidentified.....	29	62	46	27	164	33	13	0	3	49	213
Beef and veal.....	12	81	51	46	190	7	8	7	2	24	214
Lamb and mutton..	5	5	13	27	50	1	1	2	3	7	57
Pork.....	7	28	33	11	79	15	5	8	1	29	108
Total.....	53	176	143	111	483	56	27	17	9	109	592

¹ Northeastern, Southern, North Central, Western.

² State Agricultural Experiment Stations.

DISTRIBUTION OF USDA MEAT PROJECTS BY TYPE OF FUNDING



of these were on lamb, and most of the projects included meat from more than one species. In this area beef work had the most projects (13) and pork the lowest (6). Most of the economic-related meat projects are in the Southern region.

Percentage distribution of State and Hatch SAES meat projects by region is shown in the figure on p. 16. Hatch projects are supported in part by CSRS-administered Federal funds. These funds obligated by SAES and other institutions in 1969-70 amounted to \$60.5 million which was equivalent to 24 percent of the non-Federal funds obligated in the same fiscal year. State or non-Hatch projects are financed by State appropriated funds or funds other than those administered by CSRS. Two-thirds of the meat projects are classified as Hatch and one-third as State or non-Hatch.

About one-sixth of the meat projects are sponsored by the USDA agencies other than CSRS. Roughly, five-sixths of the meat projects are under the sponsorship of SAES. Two-thirds of these latter meat projects receive some support from Hatch funds. Slightly more than one-third of the meat projects are in the Southern region, just under one-third are in the North Central region and the remainder are in the Western and Northeastern regions. The number of projects devoted to beef is about twice that of pork. Lamb commands attention in about half as many projects as pork and one-fourth as many as beef. The greatest number of beef projects is in the Southern region; for pork, in the North Central region; and for lamb, in the Western region. The number of projects classified as unidentifiable due to the lack of specific species

identification appears to be increasing because of less emphasis on commodity orientation and a trend toward greater emphasis on the disciplines employed to solve the particular problems under investigation.

Most of the USDA projects concerned with meat research are in divisions of the Agricultural Research Service (ARS) and a lesser number in the Economic Research Service (ERS). These projects are also classified by the type of obligation under which they are funded: contracts, grants, cooperative agreements, and in-house. About 80 percent of the projects are in-house, that is, conducted by USDA scientists. Almost 10 percent of the projects are obligated by specific USDA contracts. Slightly less than 9 percent of the projects were obligated by grants on specific research proposals presented to the funding agency. Seven of the nine grants were made to foreign countries. Almost five percent of the projects were funded under cooperative agreements between the agency and non-agency meat scientists.

It should be pointed out that the number of projects does not necessarily parallel research effort, since funds supporting research and scientist man-years vary greatly among projects. This point will be re-emphasized later.

The distribution of effort in the 592 projects devoted to basic, applied, and developmental meat research is shown in Table 2. On the average, scientists classified 30 percent of their effort on projects applicable to basic research, 66 percent as applied research, and 2.6 percent as developmental research. Basic research in general would be considered as research conducted to uncover new knowledge often unrelated to any one specific problem. Applied research is directed to solve a specific problem—usually for immediate financial or social benefit. Developmental research is often done in cooperation with engineers for the specific purpose of developing new equipment, a new instrumentation or a new system for further experimentation.

Distribution of Scientist-Man-Years

THE scientist-man-years (SMY's) applicable to the 16 research problem areas encompassing most meat research are shown in Table 3. They are presented with the research goal, or the national agricultural objective, to which the results of the project should make a major contribution.

TABLE 2.—*Distribution of effort in projects devoted to basic, applied and developmental research*

Region	Percentage distribution		
	Basic	Applied	Developmental
Northeastern.....	33.3	66.6	0.0
Southern.....	27.1	70.8	1.8
North Central.....	38.9	55.5	4.7
Western.....	26.6	71.4	1.7
USDA.....	28.0	67.0	4.6
Average.....	30.8	66.2	2.6

Part of the broad objective of Goal II includes research programmed to protect livestock from insects and diseases. Most of this type of research is conducted by or in cooperation with veterinarians. Only 2.7 SMY's were recorded as directly involving the meat products area. This effort included some research on trichina, myodegeneration, live abscesses, etc. There is probably more "meat" effort devoted to this goal than here indicated; however, without identification within CRIS they do not lend themselves to retrieval.

Goal IV and four associated RPA's include more than 50 percent of the SMY's devoted to meat research at the SAES and the USDA. Improved acceptability, development of new products and quality maintenance are the principal endeavors of these researches. Most of the effort in Goal IV at the SAES and USDA are devoted toward new and improved meat products. SAES scientists evidently contribute no effort toward developing non-food animal products such as detergents, lubricants, and chemical intermediates from animal fats. Goal IV includes most research directed toward increasing the demand of farm products by developing new and improved products, new processes, and enhancement of product quality.

The six RPA's that encompass meat research directed to the improved efficiency of the marketing system contribute about 17 percent of the total

SAES and USDA effort into this classification (Goal V). The meat marketing effort in USDA is more than twice that at SAES, on the basis of SMY's. Such research is frequently conducted on an interdisciplinary basis between meat scientists and agricultural economists.

Research best classified in Goal VII is directed toward the protection of consumer health and improving nutrition and well-being of Americans. This research encompasses five RPA's and 48 SMY's equally divided between the SAES and USDA. It is interesting to note that most of the research on toxic residues of agricultural origin, RPA 701, is conducted in the SAES, whereas most of the microbiological and naturally-occurring toxin research is conducted in USDA. Work in RPA's 703 and 704—areas of consumer preference, time, temperature, and preparation research—is conducted at SAES. Research devoted to human nutrition is equally divided between SAES and the USDA.

Most of the meat research projects retrieved from the CRIS system fit under one or more of five research activities: protection from loss and damage; efficient production and consumer acceptability; chemical and physical properties, processing; marketing, quality, and maintenance; and nutrition and consumer satisfaction. The greatest concentration of projects dealing with meat research measured by SMY's at the SAES and USDA level is devoted to

TABLE 3.—*SAES and USDA scientist-man years devoted to research problem areas in meat projects*

Research problem by goal	SAES	USDA	Total
Goal II ¹	<i>Scientist-man-years</i>		
Diseases and parasites.....	2.7	0.0	2.7
Goal IV ²			
Improved acceptability of animal products.....	18.8	4.6	23.4
New and improved meat products.....	30.1	34.2	64.3
New and improved nonfood animal products.....	0.0	10.9	10.9
Quality maintenance.....	12.6	1.1	13.7
Total.....	61.5	50.8	112.3
Goal V ³			
Grades and standards.....	0.5	6.2	6.7
Efficiency of marketing.....	7.0	4.7	11.7
Analysis, supply, demand and price.....	0.9	9.4	10.3
Competitive interrelationships.....	1.3	0.0	1.3
Domestic markets.....	0.6	0.3	0.9
Marketing systems.....	0.0	3.0	3.0
Total.....	10.3	23.6	33.9
Goal VII ⁴			
Toxic residues.....	2.3	0.7	3.0
Harmful micro-organisms and natural occurring toxins...	0.6	5.1	5.7
Choices, habits, and consumption.....	2.1	0.0	2.1
Services, home and commercial.....	2.4	0.8	3.2
Human nutrition.....	17.0	17.5	34.5
Total.....	24.4	24.1	48.5

¹ Goal II—Protect livestock from insects and diseases.

² Goal IV—Expand demand for farm products by developing new and improved products and processes and enhancing product quality.

³ Goal V—Improve efficiency in the marketing system.

⁴ Goal VII—Protect consumer health and improve nutrition and well-being of the American people.

a better understanding of the chemical and physical properties of meat and the use of this information to improve meat products or to develop new processing techniques. This research effort requires about 40 SMY's both in the SAES and in USDA. Likewise, SAES and USDA scientists have placed heavy emphasis on identification and maintenance of meat quality and on improving market efficiency and consumer satisfaction.

The distribution of SMY's by field of science or discipline employed in solving meat research prob-

lems is shown in Table 4. Chemistry, which includes both biochemistry and physical chemistry, commands approximately 50 percent of the SMY's devoted to meat research. About 28 percent of the SMY's, except in USDA where it is considerably less, is devoted to work in physiology. Conversely, more than 80 percent of the SMY's devoted to microbiology and engineering is supported by USDA. Likewise, more than 50 percent of the economic and chemistry SMY's is in the USDA. About 63 percent of the physiology effort is in the SAES

and 47 percent in USDA. The North Central region reported the most SMY's; the Southern region ranked next. This means that on a per-project basis, projects in the North Central region carry more SMY's than in the Southern region. Also, there are more meat projects in the Southern region than the North Central region. The Northeastern region and the Western region are about equal in SMY's reported.

The average duration or time in months from the date a project is initiated until it is terminated ranged from 58.4 months in the Northeast to 77.3 months in the South. The average USDA time is 43.7 months. Projects concerned with improving consumer acceptability of animal products tend to run longer than the average duration. Such efforts are generally closely associated with production and management problems. These data suggest that USDA scientists revise or otherwise renew their projects more often than SAES scientists.

Financial Support for Research

THE average cost per SMY by regions in 1969-70 was approximately as follows: Northeastern, \$48,177; Southern, \$41,541; North Central, \$57,718;

Western, \$63,282. The average for all SAES programs was \$50,892; the average for USDA, \$45,150. The average dollar input from each region in each field of science can be approximated by multiplying the SMY's per region by the average cost per SMY. One SMY is equivalent to one employee, assistant professor or above, conducting full-time research. Any variation in \$/SMY may be due to differences in methods of reporting support funds between stations and regions.

The support per-research-problem area (RPA) in meat research at the SAES and USDA is about \$45,000, or about \$5,000 less than the support per SMY. This is due to the fact that many projects encompass more than one RPA per SMY of input.

Sources of support for all agricultural research and development programs of SAES for three different years are shown on page 22. About 51 percent of the funds is from State appropriations, 6.5 percent from product sales, 7.5 percent from industry and other sources and 35 percent from Federal appropriations. Appropriated funds (State and Federal) provided about 85 percent of the support for SAES research programs in 1966, 1968, and 1969.

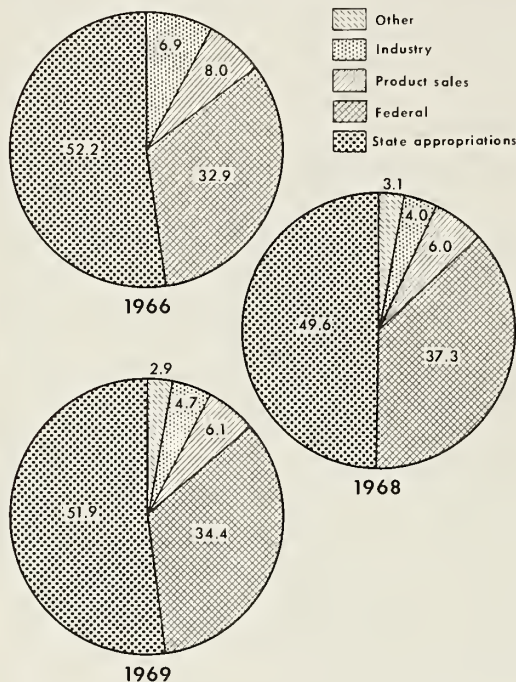
TABLE 4.—*Distribution of scientist-man-years by field of science* ¹

Field of science or discipline	Region ²				USDA	Total
	NE	S	NC	W		
<i>Scientist man-years</i>						
Chemistry.....	4.9	10.6	23.0	4.4	49.9	92.8
Physiology.....	3.2	10.7	11.9	2.3	16.2	44.3
Genetics.....	0.0	1.5	1.4	0.3	0.4	3.6
Parasitology.....	0.7	0.1	0.8	0.1	0.0	1.7
Microbiology.....	0.2	0.2	2.3	0.7	11.9	15.3
Engineering.....	0.0	0.0	0.6	0.0	4.5	5.1
Economics.....	1.6	6.3	2.0	2.4	20.5	32.8
Physics.....	0.4	0.4	0.0	0.0	0.3	1.1
Total.....	11.0	29.8	42.0	10.2	103.7	196.7

¹ Does not include research personnel below the rank of assistant professor.

² Northeastern, Southern, North Central, Western.

**SOURCE OF SUPPORT OF
AGRICULTURAL RESEARCH AND DEVELOPMENT
PROGRAMS OF STATE AGRICULTURAL EXPERIMENT STATIONS**
(Percentage Distribution)



The rest came from product sales, industry, and other sources.

The average SMY devoted to meat research in 1969–70 was supported at about the same level as the average SMY in the total SAES and USDA

programs. Although the SAES have more meat projects than the USDA, they were about equivalent in terms of SMY's and total finances in support of meat research.

Meat scientists will be interested in knowing that 1.6 percent of the total funds obligated by SAES in 1969–70 was in support of meat research. Similarly, the SMY's devoted to meat research at SAES represented 1.6 percent of the total SMY's recorded.

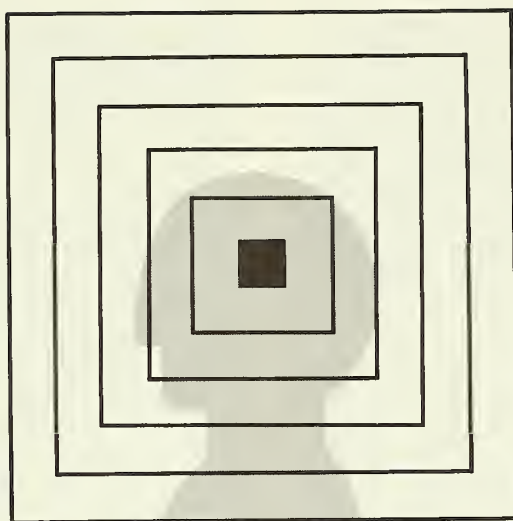
Proposed Increases in Research

IN the National Program of Research for Agriculture (1966) it was proposed that the SMY's devoted to beef marketing, acceptability, quality, and standards be increased by about 100 percent. The greatest portion of this change is expected to occur at the SAES. A similar trend for meat research on pork is envisioned. The increase indicated in lamb research is smaller than those indicated for either beef or pork. A 50 percent increase in lamb research is expected at the SAES, whereas in the USDA the proposed increase is about 130 percent.

The proposed increases in meat research appear to be greater than can be attained at expected levels of funding. Yet the consumer demands for food safety, wholesomeness, new products, and improved quality far surpass the expectations that can be attained with the present available resources. Administrators may have to resort to some pruning of projects that have ceased to serve high priority needs in order to meet the growing demands on research considered to be more important from a consumer standpoint.

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RESEARCH PLANNING: NEEDS AND OPPORTUNITIES

MARK T. BUCHANAN

GOOD agricultural research planning is a thoughtful, systematic approach to the development, elaboration and evaluation of alternative proposals for the purpose of organizing, allocating, and utilizing resources to achieve specified goals. Good planning deals with alternatives, priorities and choices. It is not decisionmaking, but it can be a tremendous aid to the decisionmaking process. Once the constraints are known, good decisions should be obvious if the planning has been properly done.

This analytical approach to alternative ways of attaining goals is a process that may be used at every level of research functioning—by the individual scientists themselves, by departmental sub-units, by the experiment station, the university, the region, or even the national science program.

Although the term, “specified goals,” comes last in the definition, the development and specification of goals must be a beginning point in planning. We

cannot get from “here” to “there” if we don’t know where “there” is—or, worse still, where “here” is. Thus, it is necessary to determine where we are and where we are headed before we can proceed with other aspects of the planning process.

The Planning Process

IN the case of the individual scientist, his goals may include one or more of the following: (1) To do significant research of his own choosing in his own area of interest, (2) to achieve recognition within and to advance his discipline or profession, (3) to achieve advancement within his institutional unit, (4) to assist his institutional unit to advance, and (5) to assist his institution to advance.

Good research planning for the individual, then, will involve his thoughtful, systematic approach to the development, elaboration and evaluation of alternative proposals to utilize his own time and other resources toward the hierarchy of goals specified. If

he already has the resources and the authority to decide how to use them, he is also the decision-maker. Undoubtedly he will make better-informed decisions as a result of his research planning effort. If he does not have the resources, he may use the planning process to improve his proposals. In this case, another goal (either stated, or hidden) may become the primary one: to secure funds with which to support research. In such a situation, he will probably apply his talents to the area he thinks is likely to yield support.

Research departments are likely to have a similar composite set of goals clustered around disciplines or fields of science related to the commodities, problems or activities with which they deal. As with the individual scientist, there could be a difference in approach for situations in which (a) the money is already under the department's control, and (b) the department is seeking additional financial support.

The question of goals becomes a bit troublesome at the experiment station level. Shall the goals for the experiment station be an aggregation of the goals of its subunits? Of its administration? Shall they be a reflection of the goals of the institution of which the experiment station is a part? Or shall they reflect the goals of farmers and their organizations or appropriations committees, or the general public?

Suppose, for example, that the goal of station administration is to do work that benefits the total public—consumers and citizens—by way of additions to basic knowledge and by application of research findings that are important to those who do not farm as well as to those who do—to those who live in the city as well as those who live in the country. At the same time, the director wants the station's resources to contribute maximally to at least the graduate teaching program of the university. This certainly seems to be a worthy set of goals from the point of view of the station administration, does it not? It is possible that such a set would be compatible also with the goals of departments and of individual scientists. But how do such goals mesh with those of the original agriculturists, the farmers? How do they look to other publics, to the

legislature, to Congress and, especially, to appropriations committees?

I suspect farmers look on an agricultural experiment station primarily as an institution created and maintained for their special benefit. They expect it to be sensitive to research needs as they see them. But the trouble is, each commodity group, each farm organization sees them differently. Nevertheless, all expect us to be their advocates.

We say, quite accurately, that the real beneficiary of our work is the consumer and the citizen. Yet this message has not been understood and adopted by either the general public or by any significant component of it, including agriculture. Whereas, T. C. Byerly says, "Agriculture has moved off the farm," effective support for agricultural research remains largely in the production sector. The understanding and support in other sectors that are necessary to effective program support have not yet evolved. Much of the support comes instead from grant sources that have their genesis somewhere else within the society.

The fact that Federal grant funds from non-USDA sources to workers within some agricultural experiment stations exceed in total all USDA-administered support indicates two things: (1) The competence and relevance of scientists employed within the institutional setting of the experiment station, and (2) the failure of the experiment station as an institution to attract its own support in such areas. Appropriations committees, the legislatures, and the Congress are ultimately responsive to their publics.

Obviously, some choices must be made:

- Do we plan to make maximum utilization of resources that are likely to be available?
- Should we seek some combination and balance among goals that seems appropriate at a given point in time?
- Should we continue to cater to and build on our existing support among farm groups?
- Should we seek to develop strong support in other segments of the population for the kinds of work we know we can and should do under the label of agricultural research?
- Should we reorganize and reorient our work so that our competencies are brought to bear on society's problems under some label other than agriculture?

This article was adapted from a paper which the author presented at the Resource Planning and Allocation Workshop, Oregon State University, April 28, 1971.

Before I discuss these questions further, I would like to digress briefly and explore some of the reasons for planning and offer some of my personal philosophy on the subject.

Reasons for Planning

BECAUSE we plan to facilitate goals or objectives, and because goals do change from time to time, it seems to me that agricultural research planning must be a continuous process. What appears to be a good set of alternatives today may be incomplete or incongruous tomorrow. More importantly, research planning can and should be done in such a manner as to achieve the best of two worlds. In other words, it should permit an individual scientist to have the incentive that comes from being able to plan his own program, but also permit planning from a centralized source to determine the levels of allocations to subject areas, commodity areas, and program areas.

How can this be accomplished? The necessary ingredient is a decision at the central level among major areas of emphasis. Funds then are allocated to these. Once this is done, scientists are recruited for programs and not only allowed but encouraged to follow their own initiative in getting the job done. As I see it, this can be done within a university setting or a civil service situation in which the rules of tenure prevail. What is necessary is a planning list of what will be done with vacancies. As a position is vacated—whatever it may be and for whatever reason—there is a spot on the planning list for the area in which the vacated position will be situated. These lists would be developed with and legitimized with the departments concerned. There would be no need for debate at the time of the vacancy as to the location of a particular replacement.

Another way to achieve the best of both worlds is to organize and administer a portion of the experiment station program under the "carrot" principle. The director would have some resources to allocate directly to scientists and their ideas or projects adjudged to be outstandingly deserving of support for one reason or another. Scientists throughout the university would be eligible to present proposals and to receive support.

You might inquire, "Isn't the director able, now, to allocate resources as he sees fit?"

The answer for the typical experiment station is a resounding, "No!"

In most cases, distribution patterns to established units are all but set in concrete. The position planning list and the establishment of a discretionary fund for allocations on a temporary basis are suggested as means by which the director might achieve some much-needed flexibility.

Recently when I was making a talk about the current status of regional and national planning within the United States, one of the listeners came forward at the end of the session to say that, in his judgment, decisions on allotments to particular programs or areas, the establishment of priorities by subject matter, by commodity, by goal, or program should be done strictly by the top administrator. There is no need, he said, to take the time of individual scientists or department heads to participate in the planning process. Each would naturally support future work in his own area.

While it is true, I believe, that central administration not only should make but *has* to make program allocations, I do not believe that this can be done effectively without consultation. The dean or director needs the knowledge and the arguments that come from individual scientists, departments, study groups, task forces, and the like. Also, the individual scientist needs to know that he has been given an opportunity to participate in the process. Hence, both for the reason that I think the director will do a better job making decisions with consultation and for the reason that providing the opportunity to consult is essential to good human relations, I think representatives of all interests should have a chance to participate in the planning process.

Another point I want to make is that planning should deal with the real world. This is one of the things that was wrong with the long-range study undertaken by a joint task force of Federal and State agricultural researchers and administrators in 1965–66. This study proposed an over-all 78 percent increase in scientist-man-years over a 10-year period. Undoubtedly one of the goals of the group was to show that increased research resources of this magnitude could be utilized effectively and would make significant contributions. An increase of this amount may have been necessary to permit some upward movement in traditional areas, while at the same time providing room for large upward thrusts in



some of the new and emerging ones. Nevertheless, the overall increase was unrealistically large. Furthermore, only one level of increase was considered. It would have been better, in my judgment, to have had, say, three levels considered: (1) a realistic increase; (2) no increase; and (3) a decrease. Better still would be an analysis of and plan for the improved use of resources at the current level, coupled with a careful assessment of items to add or subtract, in priority, in the event of opportunity or necessity.

Another important facet of the research planning process is that it should be separate from but closely linked with the administrative, decision-making process. One of the surest ways to achieve this kind of linkage appears to be, unfortunately, the stress of an actual or proposed budget cut. Then, everyone pitches in to do two types of things: (1) to show how terrible the situation would be with the cut, in an attempt to forestall it; and (2) to evolve the kinds of alternatives that would improve performance under the revised constraints. In my opinion, the latter is the better approach.

The planning process should be a part of the director's office. For local as well as regional and national planning, the decisionmakers are the directors of the stations and the administrators of the research agencies that are involved. As realistic planning occurs, communication is improved and

information is assembled, on the basis of which the decisionmakers may make more informed and better decisions than they would make otherwise.

To the extent that we plan together, across departmental and disciplinary lines, among states and with federal and industry research workers, we also enhance the communications process. No doubt, this has a significant value over and above the plans that evolve. Many people have said of regional research, for example, that the principal accomplishment to date is an enhancement of communications among scientists. At least one study has purported to show that research supported by the Regional Research Fund is highly productive—presumably as a result of intensive planning and communication.¹

Strengthening Our Research Resources

I said earlier that wise planning necessarily forces us to make some hard decisions, or choices, and I posed five questions that agricultural science must try to answer if it hopes to build on present strengths while it seeks, simultaneously, to develop new ones. Let me explore this area further.

Much of our present strength in agricultural research is in the protection, production, and natural

¹ From an analysis by Paul E. Waggoner, Connecticut Agricultural Experiment Station of forest pathology research with different kinds of administration and funding. This study was reported by James G. Horsfall at the ESCOP interim committee meeting, March 3-4, 1970.

resource base areas. Agriculture still is favored with continued support in these areas despite the emergence of a number of factors which at times appear disturbing:

- This research and its effective application with other inputs has resulted in broad gains but also massive structural changes within agriculture and the rest of society.
- A large, commercial farm-input and service sector has evolved. This industry expends more for research and development than do SAES and USDA combined.
- The beneficiaries of all of this have been consumers and the nonfarm public. Among farmers, only early adopters have benefitted significantly. Many have actually been forced out of farming.
- A host of additional problems, many associated with if not a consequence of our successes, need attention. Most of these are "off-the-farm."

As I see it, we could continue and expand effective research in the protection, production, and natural resource areas and at the same time move into others by making better use of the resources we have already. All that is required is the willingness to plan together and then to execute the plan. Ideally, the planning process should include SAES, USDA and industry. But the State stations planning together could accomplish much even in the absence of the other two.

The solution is simple: Concentrate resources on some types of work in some locations and on others in others. This can be done with quite adequate knowledge (via CRIS) of what SAES and USDA agencies are doing and with at least general knowledge of what industry is doing. The outcome—better work and more coverage with the same resources—should please producers and other groups and also speak for itself favorably among those groups on whom we rely for funding support.

The needed planning can be done within the context of present authorizations and funding procedures. Greater use of the special grants authorization, P.L. 89-106, however, would permit the addition of another "string to our bow"—an explicit means of non-formula distribution of funds among SAES.

Even under the Hatch formula, there are ways of using funds more effectively—and certainly with

the special grants system—if we care to use them. For example, under P.L. 89-106, decisions were made in advance to finance corn blight research in nine states. Hence, only these states needed to submit proposals.

On any other given problem, another group of states could be selected so that, in time, all states could be included for one topic or another. ESCOP took action at one of its recent meetings recommending to CSRS that the "earmarkings" for Hatch for "package" research be administered on a national rather than on a state-by-state basis. CSRS has agreed. Thus, some states may concentrate on rural development, others on human nutrition, and so on.

I have discussed the teaching implications of this process in an editorial in *California Agriculture*.² We should develop regional approaches to areas of concentration in teaching as well as in research.

Our State agricultural experiment station workers, with their relationships to their parent universities already have the machinery with which to relate the competence of SAES workers to other societal needs. This is attested by their success in attracting outside support. Not only do they have the competence in the relevant sciences—they have a problem-solving orientation buttressed by generations of experience. Here, too, however, planning is in order. What are to be the priorities for use of available space and facilities? Who is to pay the salaries of the scientists who propose to seek and accept grant funds? How do the proposals fit with State, regional, and national plans and with institutional goals? Much can be accomplished by outside support and I think we should foster it rather than curtail it. None of us, I am sure, would want to accept it blindly.

Finally, we have the problem of attracting consumer and general public support—and of special sub-groups of these publics—for all the good things we can and should do on an expanded basis within the State experiment station system. Some of this support will "just grow" as our volunteer efforts show above surrounding ones. But we also need to cultivate these efforts and these groups. My suggestion here is to study the matter and then apply the techniques we have used so well in other situations.

² Buchanan, Mark T., "Regional Research . . . Challenge for the Future," *California Agriculture*, Vol. 25, No. 2, February 1971.



Search for a New Food Source for Man TRITICALE RESEARCH IN MEXICO

F. J. ZILLINSKY and NORMAN E. BORLAUG

ONE of the most challenging and fascinating projects in progress at CIMMYT is the triticale research program. There are two main reasons for holding this viewpoint: (1) Triticale shows promise of becoming the highest yielding of all our small grains, and (2) its nutritive value in terms of crude protein content and availability of amino acids outranks, in some cases, that of wheat and corn.

CIMMYT initiated its triticale breeding program in 1964 in cooperation with the University of Manitoba, where earlier research had led to notable improvement in growth vigor and disease resistance. However, the original triticale populations with

which we started were not adapted to low-latitude areas such as Mexico. Because they required long days for normal development, plants failed to mature under the short-day conditions of Mexico. Plants grew rank and tall; the straw was too weak and lodged severely under a productive management system. They were also highly sterile. Diseases, too, were a problem. Races of leaf and stripe rust prevalent in Mexico almost completely destroyed the first triticales grown in the disease-favored environment of the Toluca nursery. The first objective of the new program, therefore, was to develop strains that would produce seed during the normal crop season and resist the predominant diseases. Some

TRITICALE is a derivative of a cross between wheat (*Triticum*) and rye (*Secale*). Although this manmade cereal grain has been known since 1888, it remained more or less a biological curiosity until about 40 years ago when several scientists, notably in Europe, stepped up their research programs in an attempt to develop triticales into a commercial crop.

It was not until 1954, however, when an intensive research program was initiated at the University of Manitoba, Winnipeg, Canada, that any marked improvement was achieved in overcoming some of the deficiencies of the early crosses. Until recently, much of the triticale research in North America was based on the Manitoba types. The triticale program at the International Maize and Wheat Improvement Center (CIMMYT)¹ in Mexico is particularly noteworthy—not only because of the climate-related handicaps the Center had to cope with, but also because the research pattern has many of the same approaches and attributes that characterized the successful development and worldwide adoption of semidwarf, high-yielding wheat. If triticale eventually attains the position of being ranked favorably along with other cereal grains, Review feels that the research which the authors discuss here will have made a major contribution toward that goal.—Ed.

worthwhile gains have been achieved during the intervening eight years; yet much more research must be done before triticale can become established as a cereal crop competitive with other small grain cereals.

YIELD IMPROVEMENT

ALTHOUGH average yields among triticale lines under tests have increased substantially since we began our research program, they are not yet

¹ The Center is commonly known as CIMMYT, the initials of the name in Spanish: Centro Internacional de Mejoramiento de Maíz y Trigo. Since July 1, 1971, the triticale project has been financed by the Canadian International Development Agency.

Parts of this article are based on the 1969-70 CIMMYT Annual Report and were updated where necessary.

competitive with the best Mexican wheat varieties. The present lines of triticales have several shortcomings that must be corrected before yields can be raised to the level of the best wheats. Among these are susceptibility to lodging, low tillering capacity, endosperm shrivelling during maturity, and lack of broad adaptation. Some sterility is still present, but the reduction in yield from sterility among the better strains is now much less than from other causes.

Replicated Yield Trials

GRAIN yield in Mexico among triticale strains in the early trials (up to 1968) were only slightly more than half of the best yields of wheat varieties. A major improvement in yield occurred with the selection of the more fertile types from the Cross X308, now referred to as "Armadillo" lines.

The Armadillo lines were included in replicated yield trials for the first time in the summer of 1969 at El Batán and Toluca. Average yields were well above those previously obtained at either Toluca or CIANO (Northwest Agricultural Research Center at Ciudad Obregón, Sonora, Mexico). The International Triticale Yield Nursery grown at CIANO during the winter of 1969-70 contained the best lines selected during 1968 from the Armadillo cross. The Navojón winter 1969-70 tests contained the latest selections from the same cross made in El Batán and Toluca in 1969. Performance of both groups improved relative to that of the wheat checks (Table 1). It is not expected that a similar degree of improvement will continue as a result of selections from the original 308 cross. Advanced generations of progenies from crosses of Armadillo to other triticale lines and to the dwarf Mexican bread wheats are now entering yield tests for the first time. Strains selected from these populations will hopefully provide the additional increment of yield necessary to equal that of the best bread wheats.

Lodging

ALL of the highly fertile Armadillo selections which provide the basis for the major improvements in yield, seed type, and fertility in the triticale program have weak straw. This is currently one of the more serious limiting factors to higher yields. Because of a tendency to lodge, lower nitrogen application than commonly used on wheat has had to be used in the replicated triticale yield trials. An application of 60 kg/ha of actual N has been used

TABLE 1.—Average yields of the best triticales strains compared with yields of the best wheat varieties as checks in six tests

Location and year	Triticales			Wheat checks		
	No. of strains	Ave. yield kg/ha	Yld. of top str. kg/ha	No. of checks	Ave. yield kg/ha	Yld. of top str. kg/ha
CIANO, Winter 1967–1968.	22	2663	3196	3	4213	5207
Toluca, Summer 1968.....	23	2691	3190	.....	.....	.....
El Batan & Toluca, Summer 1969.....	10	3229	3972	3	3554	3645
CIANO, Winter 1969–1970.	10	4492	4990	3	5417	6202
Navojoa, Winter 1969–1970.	18	5066	6282	4	5321	6491
El Batan & Toluca, Summer 1970.....	30	4117	5050	2	3737	4613
Navojoa, Winter 1970–71..	90	5250	6320	4	5950	6600

in tests in Sonora and Toluca. At these nitrogen levels, the yields of the best triticales approached those of the bread wheat checks. However, under conditions of maximum productivity the best triticales yields barely reached 7 tons per hectare, while yields of the best bread wheats exceeded 9 tons. Little progress in maximum yields can be expected until a substantial improvement in resistance to lodging is obtained.

Breeding for improved lodging resistance is being approached in two ways: by reducing the plant height, that is, the creation of dwarf triticales; and by increasing the straw strength at the semi dwarf level. The following three sources of dwarfing are currently being used to produce the dwarfs: (1) UM940 which possesses one of the Norin 10 dwarfing genes from the Mexican bread wheat strain P4160, (2) double and triple dwarf wheats that possess Norin 10 and other sources of dwarf genes; and (3) dwarf rye (Snoopy), a selection from an out-crossing population of Gator rye.

Improvement in straw strength without resorting to additional dwarfing was undertaken because of the difficulty in maintaining high fertility and good test weight in the dwarf selections arising from crosses involving UM940.

The origin of the parental triticales stock now being used for improving lodging resistance was a bulk outcrossing population. The original selection was found to be highly heterozygous, but appears to have a heritable source of resistance to lodging which is not incompatible with fertility possessed by the Armadillo strains. The first strains from this program are expected to enter the yield tests in 1972. Dwarf selections possessing genes from dwarf rye will require at least an additional year.

Other Agronomic Factors

Tillering—Another characteristic that significantly limits yield is low tillering capacity. There is a tendency, particularly among Armadillo strains, to produce few tillers, especially among the early maturing selections. There is an apparent association between light insensitivity and reduced tillering in at least one strain of Armadillo (X308–27Y–2M–4Y–3M–0Y–0B). Light sensitive segregates require an additional two weeks to head in Sonora, but produce at least twice as many tillers under spaced seeding. In Toluca, during the summer months, both types produce heads at more or less the same time and do not appear to differ greatly

in the production of tillers in this environment.

Adaptation—Current strains of triticales appear to be very restricted in adaptation. Changes in latitude, daylength, elevation, and probably many other factors influence their performance. Since triticales is a man-made species of recent origin with a narrow genetic base, it has not been subjected to selection for survival in competition with other species under numerous environmental conditions. To compensate for this lack of a natural evolution, it will be necessary to establish populations of triticales as genetically diverse as possible, and have these grown and selected in various environments around the world. The best selections from all possible sources can then be brought back together and again hybridized to establish a second cycle of more diverse material. Such a program requires the cooperation of many interested scientists around the world.

Cultural Practices—Special attention to production and cultural practices should result in better yields from the present strains of triticales in the future. Studies on the behavior of triticales under different seeding rates, row spacings, fertilizer levels and seeding dates have been initiated. Observations on the use of herbicides for weed control indicate wide differences among triticales in their reaction to herbicides. Generally, they are more sensitive than either bread wheat or durum wheat to both pre-emergence type herbicides and to 2,4-D.

Sprouting—Difficulties in establishing a uniform vigorous stand have been experienced on several occasions. Moist weather at maturity provokes germination in the spike. Frequently, the germination occurs before the seeds actually mature. Seeds which have started to germinate in the spike and then dry off either fail to germinate or produce very weak seedlings. Furthermore, there is a tendency for seeds harvested in a damp condition to germinate poorly, even though not sprouted. Apparently this is related to undescribed microflora adversely affecting germination.

Grain Type—Seed shrivelling is one of the major problems still unsolved in triticales improvement. After fertilization, endosperm development tends to be more or less abnormal in all triticales. The most serious abnormalities occur in the original crosses of durum and rye. It is highly possible that the failure to produce viable seeds from this cross is a direct result of abnormal development of the endosperm. Crosses between bread wheat and rye also

Triticale Status in the U.S.

Almost all of the triticales research in North America is currently being done by the University of Manitoba, CIMMYT, and private agencies. The U.S. Department of Agriculture and the State agricultural experiment stations have restricted their efforts to plant studies, feeding trials, and field testing of varieties and experimental lines.

Commercial triticales varieties are available in the United States. Rosner, developed by the University of Manitoba, and several privately developed varieties have been marketed as seed to growers in many States. Potential new varieties are under increase for release. No official production figures are available, but scattered reports indicate that 200,000 acres, or more, were planted for harvest in 1971.

USDA and State experiment station tests show triticales have yielded from less than half that of wheat, barley, or oats to essentially the equal of these crops. Claims of extremely high relative yields have not been supported by data from State or Federal tests.

Preliminary trials indicate triticales is comparable to wheat or wheat-barley mixtures in feed value for cattle, but it seems to be less palatable than barley or wheat when fed alone. USDA has announced that triticales will not be a feed grain base crop nor will it be eligible for substitution or price support.

A fairly new research effort with triticales in the United States is that of utilization in the brewing industry. In preliminary tests at the USDA Barley and Malt Laboratory, Madison, Wis., the plump, protein-rich triticales yielded malts with high extract values, high ratios of wort/malt nitrogen, and high enzymatic activity, especially β -amylase. This research is being done cooperatively with the Wisconsin Agricultural Experiment Station.—Ed.

result in badly shrivelled seeds, but an occasional seed develops sufficiently to germinate, without

employing embryo culture. When the first amphiploids are formed following treatment of the F_1 polyhaploids with colchicine, endosperm development is more normal than in the original cross, but more irregular than in the parental species. Early generations of the amphiploids produce poorly developed seeds. Usually these seeds germinate poorly and the seedlings are low in vigor. Improvement in seed can be obtained by crossing to other triticales having the same chromosome number, particularly to strains of Armadillo, and then growing advanced generations and selecting strongly for better seed type.

From the time the program started in Mexico, the triticales have been screened continually for better grain type. The most significant improvement for plumper grain was obtained with the isolation of the highly fertile strains from cross X308 (Armadillo) in 1968. The original Armadillo selections were about 3 kilograms per hectoliter heavier in test weight than the best entries in the 1968 tests.

The most advanced crosses involving the Armadillo lines as parents are now in advanced generations in the Toluca nursery. Test weights among reselections from the original strains of Armadillo cross X308 continue to improve.

A special effort was made during the 1969–70 season to select for better seed type. A special nursery containing representative lines from all crosses still maintained in the breeding program was established at Navojoa during the 1969–70 season. This nursery contained over 5,000 head rows and was used primarily to screen for good seed types. Another nursery of bulk material maintained as an outcrossing population was also used to screen for seed type. About 4,000 single plants were harvested and the grain was examined during threshing. A third group included all populations of the segregating generations (F_3 to F_6). These were also screened for seed type. About 500 plants or lines were saved from these three sources. All samples were re-examined in the laboratory from which about 125 were retained as the best seed types to serve as a nucleus for seed improvement. They will be used in crosses to other triticales and to establish an outcrossing population within the best seeded selections.



A dwarf highly fertile and lodging-resistant F_2 plant of triticale from the cross Beavor x Armadillo growing at Toluca.

TRITICALE DISEASES

ALTHOUGH triticales appear to suffer from the same diseases as wheat and rye, diseases have not appeared to be a serious limiting factor in triticale development up to now. It is very likely that as triticale production begins on a commercial scale, those diseases which find triticale a favorable host will tend to increase to epidemic proportions. It is necessary to keep a close watch on diseases which attack this crop and breed for resistant strains in the event they become important under commercial production.

The Rusts

STEM rust, *Puccinia graminis tritici*, presents very little problem in the present triticales. Practically all stains and segregating populations in the triticale nursery are resistant. Dr. Rajaram (1969–70) inoculated 468 advanced lines and strains with two virulent strains of stem rust. Strains 15–2, 4, 7, which render the resistance possessed by Gaza durum (Sr 11), the *T. Timopheevi* gene (SrTt) and that of Yuma durum ineffective, and 151–1, 2, 3, 5,

a strain highly virulent on bread wheat varieties were used because these races render ineffective many of the resistance genes now carried in both the durum and bread wheat programs. All of the lines tested were resistant. The current varieties of bread wheat and durums used in the crosses do not possess a degree of resistance equal to the resistances displayed by the triticales which were derived from these wheats. Therefore, it appears that some of the genes for resistance to stem rust must have been derived from varieties of rye.

Leaf rust, *Puccinia recondita*, appears to be much more serious than stem rust on triticales. Dr. Rajaram observed that the majority of the triticales lines tested in the greenhouse were susceptible to race 144-1, 4, 7. This race attacks Inia 66, Siete Cerros and Sonora 64. The varieties Tobari 66, Preska and Agatha are highly resistant. About half of the strains in the triticales nursery at CIANO 1969-70 were observed to have as MS to S reaction under field conditions to naturally occurring inoculum capable of infecting Inia 66 and Lerna Rojo 64. However, in yield tests and increase plots, neither the yield nor grain quality appeared to be seriously affected.

Some of the infected strains in the Navojoa nursery 1969-70 produced telia soon after the uredospores appeared. It is not known whether the environment-pathogen-race combination was particularly favorable to force this early teliospore production or whether certain triticales strains are genetically constituted to do this readily.

Stripe rust, *Puccinia glumarum*, occurs more frequently in the higher elevations near Mexico City and Toluca, than in Sonora at near sea level. Varieties of durum wheat and rye from which the triticales were originally obtained are highly susceptible to stripe rust. When the triticales program first started at CIMMYT, the triticales nursery was almost wiped out by stripe rust at Toluca. Since then, by the incorporation of resistant genes from bread wheats, durum wheats and resistant ryes, and continued screening of the segregating populations, most of the current breeding material has become resistant to the races of stripe rust occurring naturally in Mexico.

Bacterial Disease

A bacterial blight, or more characteristically a bacterial stripe, caused serious damage to many of

the triticales in the nursery at Navojoa 1969-70. It had been observed on rye and triticales in 1968 and 1969, but caused very little if any damage to the infected plants. Damage from the 1969-70 infection at Navojoa indicates that the disease is capable of completely destroying a susceptible variety under conditions favorable to bacterial development.

Several strains of triticales were under increase in Navojoa during the winter of 1969-70. Some of the strains became infected in mid-January. By mid-February the most susceptible strains were completely defoliated. All highly susceptible plots were sister lines from a fertile semi-dwarf triticales strain X308-27Y. Strains from other crosses and from other sister lines of X308 were found to be resistant in neighboring plots of the same nursery. Late-maturing varieties were not infected until the plants approached heading. Environmental conditions became less favorable as the season progressed and tended to reduce the damage on late maturing and later seeded plots.

Ergot (*Claviceps purpurea*)

ERGOT is a serious disease of rye which also attacks triticales and other cereal crops particularly when environmental conditions tend to induce sterility. The disease is common in most temperate zone areas where rye is grown. It does not occur to any extent in Mexico. Since the ergot bodies contain a poisonous substance called ergotin, their presence in the grain is highly undesirable and prohibitive as a source of human food.

Dr. E. Larter (University of Manitoba) reported that the wheat variety Kenya Farmer was resistant to the ergot disease. Crosses between Kenya Farmer and triticales varieties were made at CIANO in March 1970 in an attempt to transfer the resistance to ergot disease from Kenya Farmer to triticales. Crosses were also made between Kenya Farmer and several varieties of rye to produce new octaploid triticales. Since the disease does not occur in Mexico, it will be necessary to do the screening for resistance in an environment more favorable for ergot development.

Other Diseases

UNDER different environments, other diseases are expected to present serious production problems. Mildew occurs commonly on wheats in Europe and many wheat-growing areas of the world. *Septoria* is

also a very serious disease particularly in the Mediterranean area. Root rots take a toll of cereal crops in many grain producing areas. Many of these diseases do not occur regularly enough in Mexico to permit screening for resistance. It will be necessary to set up artificial environments to permit screening in Mexico and also to send the strains to areas where the diseases occur naturally. Cooperation is essential. Yellow dwarf, leaf blotch, necrotic spots and leaf firing occur to a limited extent on triticales at both Sonora and Toluca nurseries. These have not yet built up to damaging proportions, but should be watched as a possible source of disease problems such as occurred with bacterial stripe.

NUTRITIONAL QUALITY

TRITICALES evaluated during the past two years have proved to be a great potential source of protein and lysine. Of the 191 lines selected and evaluated from the 1969-70 small plots, protein ranged from 12.8 to 17.9 percent and lysine in the protein ranged from 2.51 to 3.84 percent. Best lines in lysine level had a protein average of 14.8 percent.

Of the 100 advanced lines of triticales from the yield tests evaluated for lysine and protein content, great variation was observed in the protein content as well as in the lysine level in the protein. Protein ranged from 10.4 percent to 20.0 percent and the lysine in the protein ranged from 2.14 percent to 3.80 percent. Environment has a considerable in-

fluence on protein and lysine content. Data from Sonora during the 1968-69 and 1969-70 seasons indicate that protein content increases and percent lysine in protein decreases with increases in the nitrogen level in the soil.

During the past year, some strains of triticales grown in different seasons and levels of nitrogen fertilization have been evaluated by Dr. F. Elliott of Michigan State University, using bio-assays employing the meadow vole. Several triticales lines have shown outstanding nutritional value of the protein in these tests.

Another development of interest was the recent discovery of a number of promising lines of Agrotriticum wheat-like derivatives. These are apparently derived from a translocation and characterized by large plump kernels of high grain test weight. Some of these lines also have high levels of grain protein.

CYTOPLASMIC STERILITY IN TRITICALE

DURING the past year *Triticum timopheevi* cytoplasmic sterility has been incorporated into triticales. The resultant crosses are completely sterile but upon backcrossing to triticales a few seeds are produced and the line can be maintained. It has been observed, in two preliminary test crosses, that a cytoplasmic sterile triticales pollinated with one of the better restorer hexaploid wheat lines gave a sur-



Visiting specialists get first-hand knowledge as one of the authors explains research being done in one of CIMMYT's triticales test plots.

prising degree of fertility. The validity and repeatability of these preliminary observations is now being explored. If verified, it could have important implications.

Triticale, unlike wheat, has large anthers which produce great quantities of pollen; in addition, the anthers are generally well exerted before dehiscing. These characteristics greatly expedite cross pollination and if an acceptable level of restoration can be found, it might become possible to produce a commercial triticale hybrid.

INTERNATIONAL COOPERATION

CIMMYT's contribution to international wheat research arose from the development of wheat varieties which could perform well in diverse areas of the world. This is particularly important in the semi-tropical and tropical areas which include many of the developing countries where food shortages exist. These varieties had to be day-length-sensitive, disease-resistant, lodging-resistant, and possess a plant structure which makes the most efficient use of the environment. Agronomic techniques and production practices had to be developed for the diverse environments existing in the developing countries in order that wheat could be produced competitively.

Young scientists had to be trained to demonstrate to farmers how the new techniques were applied in

their own situations, using the new wheat varieties to increase production. Followup research had to be organized in the developing countries to forestall disastrous losses from diseases, insects, and other problems that may arise as a result of the newly created environment. Varieties of grain had to be developed which possessed a quality suited to the eating habits of the people of the various regions. To maintain this high level of production in a continuously changing world, a regular flow of the most advanced experimental lines and varieties is made available to collaborating scientists around the world.

This is the pattern the triticale program is hoping to follow. We started with the triticales at a very primitive stage of development. Before any real impact on food production is made with this crop, we must develop it sufficiently to become competitive in yield with the best wheat varieties. It must have better nutritional quality than wheat and have acceptance as human food. Agronomic improvement, utilizing basic and developmental research, is essential to bring about this transformation. To accomplish the task quickly we must have the cooperation of competent research scientists at other centers. We collaborate directly with several research institutions in our triticale program including the University of Manitoba.

POWER SOURCE OF THE FUTURE

Nuclear fusion—the same energy source that keeps the sun burning—may well be man's major power source in the next century. It has already been produced in the laboratory on an extremely minor scale. The big problem is to create and contain a temperature of 100 million degrees which will pull atoms apart.

One liter of a deuterium-tritium gas mixture used as the fuel could produce 10 percent of the energy

requirement of the United States for 1 year. Some advantages of the system: no danger of a runaway chain reaction or accidental release of radioactivity, only minor waste problems, and abundant supplies of deuterium in sea water.

But some scientists say putting a man on the moon is child's play compared with the formidable challenge of developing usable fusion power.—*UIR Research Newsletter*, (Wis.) 6: 1, 1971.



Scope and Character of Public Plant Breeding Research in the U.S.

H. J. HODGSON



PLANT breeding activities are an important part of the total public agricultural research effort in the United States. In addition, the private sector conducts a considerable plant breeding effort. This research encompasses practically every use of plants in this country—food, feed and fiber crops, vegetables, fruits, turf, ornamentals and trees. Virtually all crops grown today are man-produced varieties of rather recent origin. The most important exceptions are the forages growing on permanent pastures and on the western rangelands.

Plant breeding is a very essential activity and an eternal one. Continually changing demands for superior varieties possessing one or several characteristics such as higher yield potential, pest resistance, better quality and consumer acceptance, adaptability to mechanical harvesting and better adaptability to adverse conditions dictate that the plant breeder's work is never done. Most livestock production is dependent upon improved varieties of field crops. Nearly all food items and many clothing items that can be purchased in the market place are available partly because of the work of plant breeders in de-

veloping feed, food and fiber crop varieties that could be produced, processed, and marketed satisfactorily. The role of plant breeders, largely but not entirely in the private sector, in providing varieties of ornamental trees, shrubs and flowers with which we beautify our environment is an important one. In recent years, sizeable efforts have been directed toward improvement of forest trees through breeding.

Justification of Breeding Effort

TOTAL cash receipts from crops, exclusive of ornamentals and trees, amounted to \$18.8 billion in 1969. If we make the reasonable assumptions that half the \$28.4 billion cash receipts for livestock products reflects values of feed crops and that 75 percent of this value is for crops that never enter market channels, we can calculate an additional crop value of about \$10 billion. Thus, crop production represents an annual on-the-farm value of about \$28.8 billion. A sizeable public and private plant breeding effort in support of that volume of production can be justified rather easily.

It is not surprising that a large effort in public plant breeding has developed. Demands within each State for improved varieties have been great. Environments are highly variable across any sizeable area and accordingly demand many varieties to meet variable needs. Research activity has responded to these needs.

Over the years, research effort has expanded in response to producer, processor, and consumer demands, often without recognition of the extent of ongoing research on the particular problem or crop. Commodity pressure groups have promoted, and often obtained, additional research inputs in plant breeding without fully realizing the extent of such research already underway. Also, new critical problems, such as southern corn leaf blight, occasionally come into sharp focus resulting in additional breeding effort rather than shifting of emphasis in already sizeable programs.

The Role of CRIS

UNTIL recently, it was not possible, except with great difficulty, to aggregate and analyze the total public plant breeding effort in the United States. Now, the Current Research Information System (CRIS) has made this feasible. It appears highly desirable that an attempt be made to characterize

this activity to provide useful information to plant breeders, graduate students, and—probably of most importance—to agricultural administrators as a tool to evaluate adequacy of resource allocation to various plant breeding activities and commodities. This article represents an attempt to characterize the public plant breeding effort in the United States.

A CRIS printout of all plant breeding projects in the system was obtained. For each of the 1,291 projects in this study, information was available on performing agency, location, project leader, title, objectives, approach, a report of progress and financial and scientist-man-year (SMY) inputs. Financial and SMY input data were for the fiscal year 1970; the progress report was for calendar year 1969. Included were projects from State agricultural experiment stations (SAES), Agricultural Research Service (ARS), Forest Service (FS) and other cooperating institutions (OCI). Public Law 480 projects conducted in other countries, but affiliated with ARS, and genetic studies on lower plants were excluded.

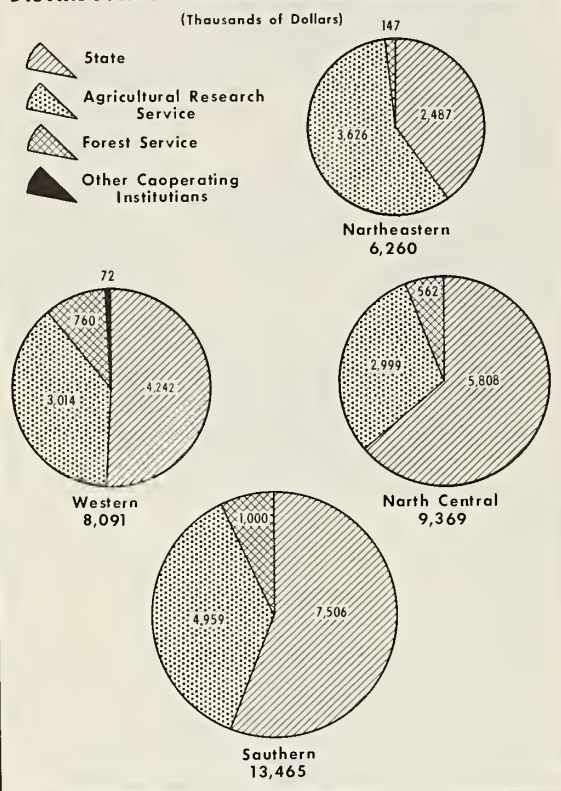
Data for each project were recorded on coding sheets. In addition to project identification, information was recorded on performing agency, State in which research is located, major objective, commodity, and SMY and dollars expended. Major objectives were classified in 10 categories, and, for each project, classification was determined from reading the title, objectives, approach, and progress report. In the majority of cases, a project was assigned to one primary objective in accordance with the project's major thrust; in some cases where two objectives seemed to receive about equal attention, project inputs were so divided.

All major field crops, vegetable and fruit crops, and trees were included in commodity classification. Each individual project was classified to a single commodity if information in the printout indicated dominant activity devoted to that commodity. If the project dealt about equally with only two commodities, distribution of inputs was made in that fashion. If a project dealt with multiple commodities, it was relegated to a collective classification such as small grains, vegetable crops, or forages.

Admittedly, such classification of objectives and commodities leads to some degree of error, and it must be recognized that, given some rather inadequate progress reports, classification was sometimes

PUBLIC PLANT BREEDING RESEARCH EXPENDITURES DISTRIBUTED BY REGION AND PERFORMING AGENCY

(Thousands of Dollars)



a matter of judgment. However, each project was classified as objectively as possible and, considering the large number of projects involved, small errors should tend to average out. Input totals for objectives and commodities should, therefore, reflect actual inputs fairly accurately. After all projects were classified and coded, cards were punched, a computer program was written and data were summarized at the computer center of the College of Agriculture and Life Sciences, University of Wisconsin.¹ I have attempted to summarize and analyze a rather large volume of data in the accompanying tables.

The Broad Picture

TABLE 1 indicates the dollar and SMY inputs of the four performing agencies and the total public plant breeding inputs. State inputs include those

¹ I am indebted to Mr. Frank Kooistra, Assistant to the Director, Wisconsin Agricultural Experiment Station for card punching and computer programming.

supported by State appropriations, federal funds distributed to states by the Cooperative State Research Service, industry gifts and grants, and other sources except ARS. State inputs amount to slightly more than half the total effort. ARS and Forest Service contribute to a total USDA input of slightly less than half the total. Expenditure per SMY is about \$5,000 greater in USDA research than in the states. The total plant breeding research investment of \$37 million represents a very modest 0.13 percent of the total annual value of crops. This indicates, on the average, that in each State there are about 16 SMY's devoted to 26 plant breeding research projects.

Aggregation of research expenditures of the several agencies by region is given in the figure on p. 38. Note that the heaviest investment in plant breeding research is in the Southern region. It is interesting to compare these data with regional figures on harvested crop acreage given by Keith C. Barrons in an earlier issue of *Review*.²

Table 2 gives a broad picture of the relative importance agricultural science attaches to the various research objectives in the overall plant breeding programs. For example, breeding for improved yield and pest resistance amounts to 53 percent of the total effort on a dollar basis. At the low end of the scale is breeding for adaptation to mechanical harvest (1 percent) which undoubtedly reflects the relatively low value of crops not yet adapted for such harvest.

The objectives of yield and pest resistance obviously are not completely independent. Success in breeding for disease and insect resistance in most commodities is essential if the genetic potential for yield is to be achieved in any variety. Similarly, pest resistance is a requisite for acceptable market quality in many commodities. Research on these two objectives has been highly successful as is proven by the ample supplies of high quality products available to consumers at comparatively low real cost. Without that success our food and fiber supplies would be much lower, prices would be much higher, and insults to the environment would be very much greater resulting from attempts to control insects and diseases in the production of needed food and fiber supplies. Breeding for pest resistance takes on

² See *Agricultural Science Review*, Vol. 9, No. 2, 1971, p. 35.

TABLE 1.—*Public plant breeding research by performing agency, 1970*

Agency	Research expenditures	Percent of total expenditures	Scientist-man-years	Thousands of dollars per SMY
	\$1,000	Percent	Number	\$1,000
State.....	20,047	54	446	45
ARS.....	14,590	39	294	50
FS.....	2,468	7	49	50
OCI ^a	72	.....	2	36
Total.....	37,185	100	790	^b 47

^a Other Cooperating Institutions.^b Average.TABLE 2.—*Public plant breeding expenditures by major objective and number of projects devoted to each, 1970*

Major objective	Research expenditures	Percent of total expenditures	Scientist-man-years	Projects
	\$1,000	Percent	Number	Number
Yield.....	9,664	26	202	319
Disease resistance.....	8,378	23	188	236
Insect resistance.....	886	2	18	40
Dis. & Ins. resist ^a	639	2	17	23
Quality.....	2,925	8	61	87
Variety evaluation.....	4,399	12	93	249
Mechanical harvest.....	456	1	9	16
Genetics.....	6,573	17	134	209
Morph-physiol.....	768	2	18	44
Miscellaneous.....	2,497	7	49	68
Total.....	37,185	100	790	1,291

^a Includes projects with emphasis on both.

new significance as the likelihood of reduced usage of pesticides increases.

Genetic studies—those directed to understanding the genetics of various crop attributes—command 17 percent of the total input and have contributed

in no small measure to the success of breeding for most objectives.

Breeding for morphological and physiological traits has received only minor inputs; however, rapidly developing knowledge of the basic physiol-

ogy of crop plants should provide the basis for materially increasing efforts in breeding for these traits. The attendant problems in this area indicate the compelling need for plant breeders and plant pathologists to become much more closely involved with plant physiologists and biochemists. Most significant future gains in breeding for either yield or pest resistance probably will derive from a better understanding of the major physiological components of yield and physiological, biochemical, and morphological mechanisms of resistance of plants to diseases and insects.

Twelve percent of the total effort is directed to

evaluation of varieties and advanced breeding materials. In this analysis, projects so classified were those not considered as integral parts of breeding programs. To a degree, this is a necessary effort to provide information for extension personnel and farmers. However, some of the input in this area may have to be diverted to more pressing needs in the future.

Breeding for adaptability to mechanical harvest constitutes a very small proportion of total effort and largely relates to fruit and vegetable crops. Breeding for quality constitutes about 8 percent of the total and probably is increasing considerably.

TABLE 3.—*Public plant breeding expenditures by commodity and source of funding, 1970*

Commodity	State	ARS ^a	Total	Commodity	State	ARS ^a	Total
<i>Thousands of dollars</i>				<i>Thousands of dollars</i>			
Corn.....	1,805	904	2,709	Grasses.....	785	454	1,239
Sorghum (grain).....	629	96	725	Forage (gen.).....	235	60	295
Rice.....	83	199	382				
Wheat.....	1,089	1,126	2,215	Veg. crops.....	1,144	552	1,696
Barley.....	433	452	885	Carrot.....	69	59	128
Oats.....	292	354	646	Tomato.....	618	406	1,024
Rye.....	6	.....	6	Bean, pea.....	621	287	908
Sm. grain (misc.).....	700	194	894	Sweet corn.....	155	.....	155
				Cucurbits.....	384	95	479
Soybean.....	708	864	1,572	Sweet potato.....	131	72	203
Peanut.....	328	217	545	Crucifers.....	71	.....	71
Safflower.....	5	258	263	Onion.....	30	59	89
Other oilseed.....	108	349	457	Potato.....	588	438	1,026
Cotton.....	1,124	1,110	2,234	Tree fruit and nut.....	1,167	627	1,794
Other fibers.....	.....	60	60	Small fruits.....	696	492	1,188
				Citrus.....	233	281	514
Sugar cane.....	259	630	889				
Sugar beet.....	48	425	473	Forest trees.....	1,019	 ^b	3,559
Sorghum (sweet).....	21	14	35	Christmas trees.....	29	.....	29
Tobacco.....	459	655	1,114	Orn. trees, shrubs.....	315	1,181	1,496
				Flowers.....	248	236	484
Alfalfa.....	490	490	980	Turf.....	263	17	280
Other legumes.....	478	541	1,019				
Sorghum (forage).....	56	.....	56	Basic genet ^c	1,405	52	1,457

^a Agricultural Research Service.

^b Includes \$2,464 in Forest Service and \$72 in Other Cooperating Institutions.

^c Plant genetic research not directed to specific crops.

Meaningful Ratios

IN the analysis of public plant breeding expenditures by commodity (Table 3) and by major crop categories (Table 4), a few meaningful patterns may be discerned. For example, the grain crops—especially corn and wheat, our principal sources of energy for food and feed—receive the major inputs. Ranking next, as might be expected, are vegetable crops including potatoes. Within the individual commodity groups (Table 3) what may appear to be imbalances between State and ARS research may really reflect the status of a crop on a national basis and its adaptability to a particular region. For example, sugar crops are grown in only a few states, yet the crops are highly important nationally; hence the federal inputs outrank those of the states. Cotton is an exception to this input imbalance, even though it, too, is regarded as a regional crop while at the same time being important to the national economy. No single factor, however, can be cited for the similarity in State and ARS input, but rather it is the cumulative effect of a number of factors, not the least of which is the need to breed varieties better adapted to cope with problems presently facing cotton producers.

Table 5 provides an analysis of the plant breeding and total research effort on major crops in relation to farm value. Plant breeding inputs in relation to farm value are very high for sugar crops, cotton, and vegetables, while corn and forages are at the other extreme. Similarly, some rather interesting disparities are clearly evident when one compares the farm value of several crops (first column) with the total research investment (fourth column). Farm value per dollar of research investment (last column) ranges from a low ratio of about 60 to 1 for cotton to a high of about 450 to 1 for corn and forages. In other words, for every \$59 worth of cotton production, we spend \$1 for research, but for every \$445 worth of forage production, we still spend just \$1 for research. It is not suggested that this ratio should be the major determinant of resource allocation. Actually, many other factors are involved. Nevertheless, this ratio should be a very valuable yardstick to research administrators in maintaining an appropriate balance among the major commodities. From this analysis, it would appear that some commodities are very heavily researched at the present time. The very high research input in relation to farm value suggests that the ongoing research needs considerable re-evaluation with respect to relevance in solving major problems of a commodity.

TABLE 4.—Summary of expenditures by major crop categories

Major crops	State	ARS	Total
<i>Thousands of dollars</i>			
All grains.....	5,138	3,324	8,462
Oil seeds.....	1,150	1,687	2,837
Fibers.....	1,124	1,171	2,295
Sugar.....	329	1,069	1,398
Tobacco.....	460	655	1,115
Forages.....	2,046	1,545	3,591
Vegetable crops & potatoes.....	3,813	1,968	5,781
Fruits and nuts.....	2,096	1,400	3,496
Trees.....	1,048	.....	^a 3,588
Ornamentals.....	826	1,434	2,260

^a Includes \$2,468 in Forest Service and \$72 in Other Cooperating Institutions.

TABLE 5.—Farm value for important crops and plant breeding and total research

Crop	Farm value ^a	Plant breeding expenditures	Ratio: column 1 to column 2	Total research expenditures ^b	Ratio: column 1 to column 4
<i>Thousands of Dollars</i>					
Corn.....	5,178,781	2,709	1,912	11,463	452
Wheat.....	1,786,156	2,215	806	9,490	188
All grains ^c	9,164,375	8,462	1,083	30,199	303
Oilseeds.....	2,985,305	2,837	1,052	12,702	235
Cotton and cottonseed.....	1,210,994	2,295	528	20,253	59
Sugar crops.....	480,480	1,398	344	4,580	105
Tobacco.....	1,296,781	1,115	1,163	6,784	191
Forages, range, pasture ^d ...	9,021,000	3,591	2,511	20,383	445
Vegetables and potatoes... ^e	2,781,324	5,782	481	24,775	112
Fruits and nuts..... ^e	2,206,259	3,570	618	29,475	75

^a Data from Agricultural Statistics 1970, USDA.^b Data from Table II-B, Inventory of Agricultural Research Vol. II, USDA.^c Includes corn and wheat.^d Calculated: 225,525,000 tons of forage feed units consumed by all livestock in 1969 (from Table 91 USDA Bulletin 446, ERS, 1970) × \$40.00 (corn price per ton). A feed unit equals feed value of one pound of corn.^e Data from Farm Income Situation Supplement, August 1970.

TABLE 6.—Distribution of expenditures by major crop category and major research objective, 1970

Commodity	Yield	Disease resistance	Insect resistance	Dis. and ins. resistance ^a	Quality	Variety eval.	Mechanical harvest	Genetics	Morphology-physiology	Misc.
<i>Thousands of dollars</i>										
All grains.....	2,650	1,496	368	298	789	791	.....	1,576	402	92
Oilseeds.....	1,451	627	1	57	234	197	.....	190	44	37
Fibers.....	662	528	148	.....	183	194	16	487	.....	78
Sugar.....	764	431	.....	.....	120	72	.....	10	.....	.....
Tobacco.....	40	699	.....	.....	165	.....	.....	197	.....	13
Forages, range, pasture.....	1,704	168	145	220	125	370	.....	629	99	131
Vegetable crops and potatoes.....	1,303	2,017	70	64	417	586	427	550	33	313
Fruits and nuts.....	550	1,109	3	.....	680	642	12	175	31	367
Trees.....	423	127	153	.....	.....	941	.....	777	9	961
Ornamentals.....	.....	1,077	.....	.....	73	260	.....	365	74	412

^a Includes projects with emphasis on both.

Data in Table 6 are somewhat similar to those in Table 2, except that a more detailed breakdown in research objective of individual crops is presented. Here again, some meaningful patterns may be observed. Note that breeding for improved yields outranks breeding for disease resistance in all but four of the major crop categories—tobacco, vegetable crops and potatoes, fruits and nuts, and ornamentals. (Breeding for improved yield, however, would obviously not apply to ornamentals.) In most cases breeding for disease resistance outranks breeding for insect resistance—probably because it has been a research goal for a longer time and because of a long-held philosophy that insect control could be readily achieved solely by use of insecticides. What looks like an obvious disparity is the relatively low emphasis placed on breeding for disease-resistant trees. This probably is because much tree breeding is of recent origin and still is necessarily concerned primarily with evaluation of germ plasm sources.

Under the category of breeding for mechanical harvest, the major remaining problems are apparently in vegetables—or at least the research emphasis would so indicate. The lower priority on breeding for mechanical harvest of fruits and nuts

may indicate the relative economic importance of certain crops, the difficulty of achieving success, or the fact that breeding studies are not pertinent to the problem.

* * * * *

In evaluating the information in this survey article, readers should realize that the data become approximate when viewed in this fashion. And since data are presented for only a given point in time, trends are not apparent. In other words, this survey is an analytical profile of the research status on plant breeding as of the period for which CRIS data were available. Hopefully, those who are concerned with the execution and administration of plant breeding research may find it both interesting and useful.

Naturally, not all commodities have problems of the same magnitude or ease of solution; therefore, some will require proportionately more effort than others. But at the same time, it must be realized that powerful commodity interest groups can effect continually increasing efforts on commodities of their interest to a point that is beyond balance and perhaps even beyond the public interest generally.

GOATWEED BEETLES LOVE GOATWEED

About 30 years ago, more than 75,000 acres of rangeland in Kootenai County, Idaho could not be used for grazing because of a heavy infestation of goatweed. Other counties were also seriously infested. In 1940 Idaho entomologists began a program of attempted biological control by importing beetles from Australia that feed exclusively on goatweed. In fact when they can't find goatweed, they die. Thus, they cannot become a pest themselves.

The tests were favorable, the beetles increased, and when populations were great enough, they were released into the goatweed-infested rangelands. The hungry beetles went to work and literally ate them-

selves out of house and home. The grasses came back to the rangeland, and the ranchers applauded the beetle.

How much this particular research effort has meant in dollars and cents is difficult to pin down. Certainly the increased animal-carrying capacity of rangeland formerly infested with the weed has meant much to the beef industry in the State. For instance, one ranch in Nez Perce County reported an increase in carrying capacity of 6 to 7 times after the beetles had been used.—*Idaho Agricultural Science*, 56: 3, 1971.

SCIENCE NOTES

SEX SIGNALS DETECTED

IF an insect has antennae, entomologists can now tell what sex attractants may be useful in controlling excessive populations of that insect. It's all done with a device called an electroantennogram (EAG).

EAG was first described by a German scientist, D. Schneider, in 1957. A Cornell University graduate student, Andre Comeau, has extended the use of EAG to determine sex attractant structures.

First an antenna is clipped from the head of a male insect, then transferred to a piece of wax set in a dish of salt solution. A glass capillary electrode is then fitted to the antenna and wired to a preamplifier. Another wire from the salt solution completes the circuit.

As air is blown over the antenna, various test compounds are injected into the air stream by puffing air through a pipette containing the compounds. When a test chemical has sex-attractant properties, the antenna responds by changing polarization—which in turn can be detected by the electrodes, and the amplified change is transformed to a visual signal on the oscilloscope. The antenna is so sensitive that it can tell the difference between a 12-carbon chain acetate and one with an 11-carbon chain.—*New York's Food and Life Sciences Quarterly*, 4:4, 1971.

Mushrooms deadly enough to kill a human are relished by red squirrels during summer months.

NATURE'S INSECTICIDE

What makes some strains of barley more resistant to greenbugs than others? Biochemists at the Oklahoma Agricultural Experiment Station have discovered that it's a higher concentration of benzyl alcohol.

Benzyl alcohol occurs naturally in the plant and generally is not toxic to the insect. In laboratory tests, however, the presence of benzyl alcohol reduces the greenbugs' rate of reproduction and their survival rate.

Entomologists are now trying to determine how this discovery can be put to practical use. Among planned tests are adding benzyl alcohol to irrigation water used on sorghum, and spraying a solution directly on wheat and other greenbug host plants.

Because the compound is naturally present in some plants, it is not regarded as an insecticide. Moreover, it is relatively cheap and easily available, soluble in water, and fairly harmless from the standpoint of application danger or residue build-up.—*Agriculture at OSU*, 1: 3, 1971.

Hedge rows in the British countryside may look pretty to tourists, but they're a nuisance to farmers, who have been cutting them down at the rate of about 4,000 miles a year since World War II. But at that rate it will take them nearly 100 years to get rid of those encroaching on farm land.

OZONE TOLERANCE

Levels of ozone, the product of photochemical reactions in the atmosphere, are toxic enough in southwestern Ontario to cause widespread damage to tobacco and white beans, producing a bleached, scorched appearance and leaf mottling.

To avoid losses from ozone damage, farmers in this area may have to grow only tolerant cultivars or species. Tests show that the most susceptible species are onion, cucumber, and potato, in that order. Greenhouse-grown plants exposed to ozone concentrations of 100 parts per million for 4 hours showed marked damage effects.—*Canadian Jour. Plant Sci.* Vol. 51, 1971

More than 250 species of insects have developed insecticide resistance since 1946. From 1908 to 1946, only 10 had developed resistance.

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